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Bell Laboratories

RECORD

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Bell Laboratories **RECORD**

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Contents

Cover *At Milwaukee, Wisconsin central office, two student operators (foreground) use energized training facilities developed at the Laboratories (see page 174).*

As you travel along our crowded aerial highways, a vast system of air traffic control guides your plane to help bring you safely to your destination. An integral part of this system is Bell Laboratories . . .

M. E. Ozenberger

Voice Communication System For Air Traffic Control

Every day there are more than 180,000 take-offs and landings in the United States. Last year passenger miles approached the 39 billion mark. To control this huge volume of air traffic, the Federal Aviation Agency maintains 30 strategically located control centers which have jurisdiction over aircraft flying in their respective areas. These areas are divided into sectors based on the number of airways and the amount of air traffic. The personnel in each sector of a control center include a controller and an assistant controller. The controllers are supported by radar controllers and flight-data controllers. Flow-control coordinators supervise the activities between sectors, and a watch supervisor is responsible for over-all operation of the main control room at an air route traffic control center.

Here is what happens in a typical commercial airline flight. Before take-off, the airline files the pilot's flight plan by teletypewriter with the control center. The flight plan includes such data as point and time of departure, proposed altitude and airspeed, destination, and estimated time of arrival. A flight-data controller places this information on a set of paper flight strips (*shown on page* 158) and passes a copy on to the controller handling the sector in which the plane is taking off. The airport air traffic control tower obtains clearance for the flight by calling the controllers over a private telephone line. In clearing the aircraft for take-off, the controllers assign the plane an altitude that does not conflict with other aircraft flying the same route. As the plane flies over the sector, it is viewed in the control center as a white blip on a radar-scope. While the plane is airborne, controllers use radio microphones,

telephone instruments, and radar to guide it to a safe landing.

When the plane passes over one of the many check points along its route, it radios the time of passing, altitude, and the pilot's estimate of the time it will take him to reach the next check point.

At any time during the flight, the controllers may direct the pilot to change altitude or lose time to ensure safe vertical, lateral, and longitudinal separation from other aircraft. This communication is by government-owned radio, much of which is remotely controlled over Bell System line facilities. In addition to this direct communication there are many radio messages which are relayed to and from airline company radios by private telephone lines. More than 90 per cent of the phone communication with a control center must pass through a telephone switching system.

This communication system connects control centers not only with airports and airline dispatching facilities, but also with weather bureaus, military aircraft control stations, and other air route traffic control centers. Within a control center there are also interconnecting facilities

Often it is necessary for controllers to confer in directing air traffic. Here, a flow-control coordinator (right) issues flight instructions to aircraft in various sectors of the control region.

which enable a person at any console to talk to anyone else in the control room. This communication network is the largest nonmilitary private-line system in the world.

The story of the latest version of this communication system really begins in 1956. It was then that the Civil Aeronautics Administration, the American Telephone and Telegraph Company, and Bell Laboratories formulated the requirements for the 300 Switching System. The 300 System was designed to be extremely adaptable and able to handle a large volume of calls. It consists of racks of wire-spring relays and crossbar switches installed in an equipment room. It also includes equipment inside a control room where there may be as many as 120 consoles each having access to up to 130 lines. At each console, the 300 System provides special keys, lamps, loudspeakers and telephone sets. In short, the system includes all the signaling, switching, and voice-communication facilities for handling as many as 40,000 calls a day. This article considers the operation of the console and the switching equipment for the 300 System.

One of the main objectives in designing the 300 System was to minimize the space required for the telephone equipment at the controller's console and still permit fast access to all lines. About 90 per cent of a controller's calls involve 12 or fewer lines. To expedite the placing of calls over these frequently used lines, each one is assigned a "direct-access" key. This means

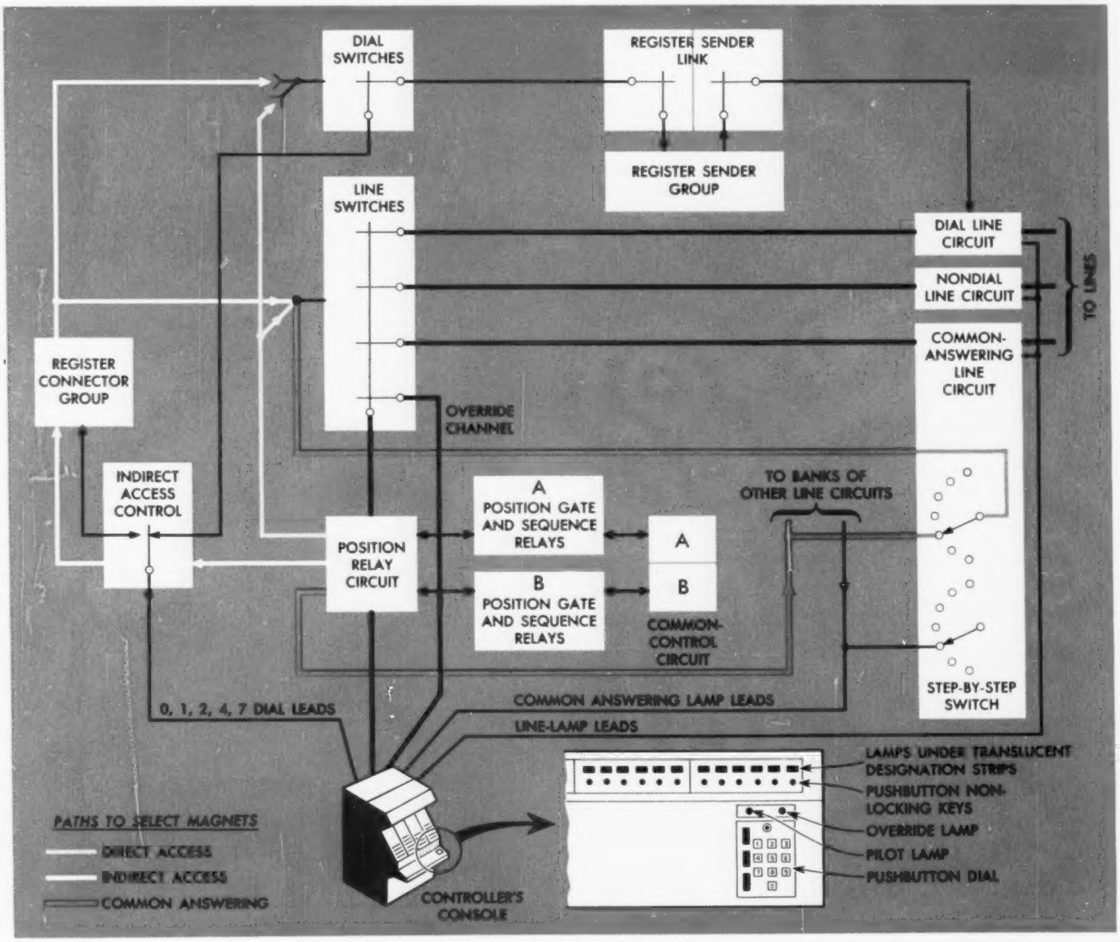
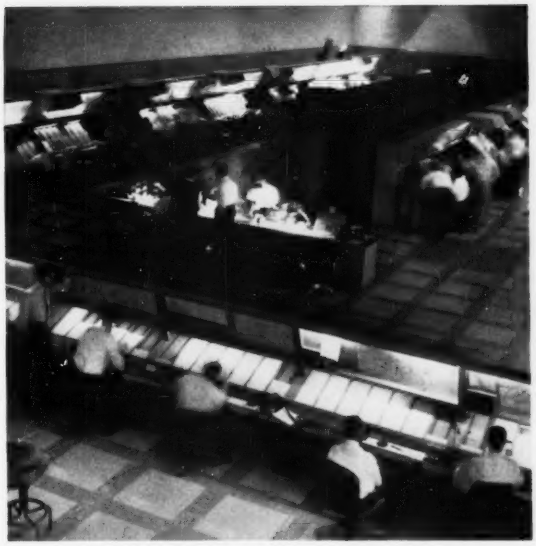


Diagram of one of the two line-connector frames for the No. 300 Switching System. The number of register connectors and register senders varies from three to five, depending on size of the system.



Air Route Traffic Control Center at Hampton, Ga., showing flight-data controllers in foreground. Consoles in center are supervisory positions.

that if a controller operates any of these keys he is immediately connected to the line. The number of line keys at a console can be increased if more are required.

Because it would be impractical to have direct access to all lines, Laboratories' engineers designed a method of "indirect access." To make such a call, the controller presses an indirect-access key, dials a two- or three-digit code on his pushbutton dial, and in this way connects to any line or other controller in the center.

Another feature designed to save space at the console is called "common answering." Certain lines, usually those to airline offices and airports, and PBX tie trunks permit inward dialing. The controller uses a single common-answering key to answer calls from all lines and trunks of this type. There are three common-answering lamps at a controller's console. When one call comes in, the first lamp lights up, a second call lights the second lamp, and so on. To answer a call, a controller simply presses the key. When that call is ended, he presses the key again (which releases the first line), and answers the second call. As soon as the controller answers a call, the lamp signals shift down.

Each key for direct-access lines has a lamp associated with it. A flashing lamp indicates an incoming call, a winking lamp indicates a held line, and a steady lamp indicates a busy line. In a system using locking keys, the operated position of a key indicates a connected line. But the use of nonlocking keys in the 300 System required the introduction of a new lamp signal called "flutter" for indicating to the controller which line is connected to his telephone set. The flutter signal is produced by a transistor interrupter which interrupts the lamp circuit at the rate of 12 pulses per second.

This is how the lamp signals operate: A line usually has direct-access keys and lamps at a number of consoles. If the line is idle, the lamps are dark at all of these consoles. When an incoming call appears on the line its lamps flash at all consoles. When a controller answers the call, the flashing lamp at his console changes from flashing to flutter. At the other consoles, the lamps change to steady to indicate that the line is busy. A controller may connect to a busy line when there is a need for it. This causes the steady lamp at his position to change to flutter without affecting the other lamps.

Systems of this type usually have a pilot (position-alerting) lamp and an audible signal at each position to alert a controller when he receives a call. In addition to the customary pilot lamp, the 300 System has two innovations for alerting the controller and for expediting the answering of incoming calls: position blanking and an electronically generated chime signal.

Operating Procedures

A typical array of lamp signals in front of a controller might include several steady lamps and several flashing lamps representing unanswered calls to other positions. Now suppose the controller receives an incoming call. The line lamp and pilot lamp flash. The controller must know immediately which flashing line lamp to answer. To aid him in this situation, the system provides position blanking which blanks (retires) all lamps except the flashing pilot lamp, the flashing line lamp representing a call directed to him, and a fluttering lamp if he is connected to a line. When he answers the call, the fluttering lamp and the pilot lamp go out and the flashing lamp changes to flutter. All the blanked lamps are restored. The controller may cancel the blanking feature at any time by turning a key.

In addition to the flashing pilot lamp, an incoming call turns on the chime signal in the loudspeaker on the console. This feature was developed to meet the specific requirements of air route traffic control centers. The chime signal

Flight-data controller plots flight plans from data received by teletypewriter from airline dispatching agencies. Note paper flight strips on console. Pushbutton dial and line keys in foreground.

takes up no extra space at the console, since it uses the loudspeaker which is required anyway. The system provides for as many as five chime frequencies so that a controller can readily distinguish his signal from the signals at adjacent positions.

The urgency of much of the communication in air route traffic control centers requires a switching system somewhat different from the usual systems. A controller or supervisor must be able, at all times, to reach any line regardless of whether it is busy and regardless of the amount of traffic through the system. This means that a link arrangement, commonly used in central offices, is not acceptable because it would limit the number of calls in progress at the same time. Instead, the crossbar switches are arranged in a field with a complete multiple of the verticals and a complete multiple of the horizontals. Positions occupy the verticals, and lines and intercommunicating channels occuy the horizontals.

With this arrangement, there is a convenient and fast method of intercommunicating between controllers' positions. To connect to these channels, a controller usually employs indirect access, but if he needs to call another controller frequently he may have a direct-access key installed. The intercommunicating channel operates on an override basis. This means that when a controller connects to an override channel he is immediately connected to either the telephone set or the loudspeaker of the called controller. Such calls, because of their importance, override all others and are received without requiring any action by the party called.

Each controller has a key which permits him to switch his incoming override channel either to his telephone set or to his loudspeaker. In addition to using override to converse with controllers, a supervisor or controller may use it to monitor another controller for the purpose of lending assistance or training. If one or more persons are connected to a controller's telephone set a lamp lights up at his console.

To prevent trouble in common-control equipment from causing complete failure of the system, a crossbar switch field is divided into two line connector frames. Each frame has its own common-control circuit. For added reliability, each common-control circuit is divided into A and B sides, which alternate in handling calls on a frame. If there is trouble on one side, it automatically takes itself out of service and the other side handles all traffic on the frame.

Whenever a controller presses a line key, he operates and locks an associated key relay in his position-relay circuit which is located in the equipment room. This releases any previously operated key relay in his relay circuit and causes a request for the common-control circuit to be registered in the position-sequence relay circuit. The common-control circuit and the position relays acting together perform a connecting cycle requiring 0.2 second. This closes the proper cross-points. During this connecting cycle, the operated key relay establishes the operating path for the select-magnet of the called line.

Indirect Access

When a controller doesn't have a direct-access key for a particular line or override channel, he uses the indirect-access key. This causes the indirect-access control circuit to connect an idle register connector to his position-relay circuit and connect the five dial leads from his pushbutton dial to the register connector. The "ready" lamp on the pushbutton dial shows a steady signal which tells him to start dialing. By pressing one button at a time, he dials the two- or three-digit number of the called line.

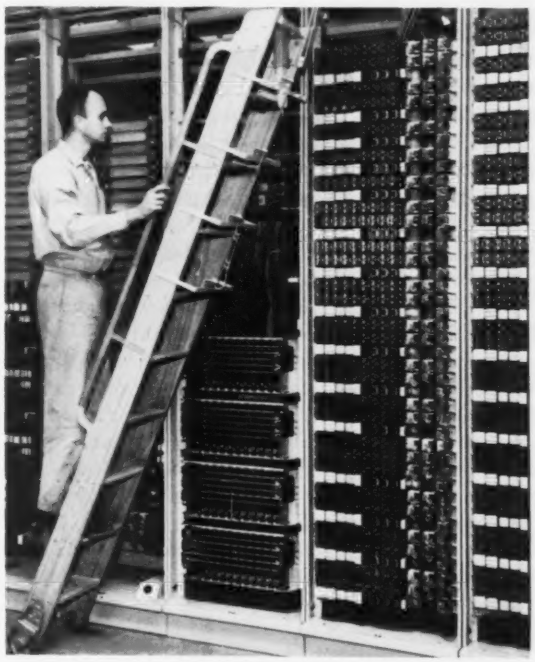
As the controller keys each digit, the dial closes two of the five dial leads on a standard two-out-of-five code basis. This registers the digits by operating relays in the register connector. The register connector then requests the position-relay circuit to call in the common-control circuit to initiate the connecting cycle. In this case, however, the path for operating the required select magnet is established through the register connector. Here the pattern of operated register relays representing the dialed number determines which magnet operates. At the console, the lamp associated with the indirect-access key flutters, indicating that the controller is connected to the line. If the controller sees the dial ready lamp change from steady to flashing while dialing he knows that he has dialed incorrectly. To re-dial the controller must first press the "clear" button on his dial.

Laboratories engineers found that the most economical method of implementing the common-answering service was to use step-by-step switches. As discussed before, common-answering stores up to three waiting calls from certain local lines and PBX tie trunks and automatically determines the order of answering on a first come, first served, basis. Each line and each tie trunk terminate in a step-by-step switch in the 300 System.

To illustrate the operation of this feature, assume that there are three calls to a controller. This means that three step-by-step switches are dialed to the bank terminals of the called position. This lights lamps 1, 2, and 3 at the controller's console. Any subsequent calls to the controller receive a busy tone. The controller answers the first call by pressing his common-answering key; this initiates a connecting cycle similar to direct-access operation. During this connecting cycle, there are three step-by-step switches resting on the same set of bank terminals (the set associated with the called position). This connects the select-magnet operating lead from the position relay circuit to all three switches. But the switch which is lighting the first lamp is the only one with its relays in position to close the lead through to the corresponding select magnet on the crossbar switches.

After the controller answers the first call, the first step-by-step switch is released. Then the relays in the second and third switches advance so that the second switch lights the first storage lamp and the third switch lights the second storage lamp. This progression of calls continues as more calls are answered and received.

Some lines, including the PBX tie trunks, require outward dialing. A controller places a dial-line call in the same manner as a nondial line call. He may use either direct access or



Switching equipment for the No. 300 System is installed in the equipment room at a control center.

indirect access. As shown in the drawing on page 156, there is a field of dial crossbar switches, with a horizontal for each dial line. When a dial line is seized, crosspoints on this field close. This connects the controller's pushbutton dial to the register-sender link. The link connects the five pushbutton dial leads and the line to an idle register sender. A steady signal at the dial-ready lamp tells the controller to start dialing. The controller then dials the number which may vary from one to seven digits depending on the type of call being placed.

As he presses the dial buttons, he registers each digit on a set of reed relays in the register connector. The register connector translates the number into decimal code and transmits it out on the line in the form of dial pulses.

Additional Lines

In addition to the dial lines, there are various other lines coming into a control center. All of these terminate in a variety of the line circuits which are part of the 300 System. Besides providing the proper transmission elements these line circuits perform a number of control and signaling functions. For example, the conventional two- and four-wire toll lines may use manual ringing for signaling in both directions, or they may have loudspeakers at the distant end for direct voice calling. At the control center, they may connect to the console loudspeakers for alerting or for passing messages directly to the controller. Also, a voice-operated switch may be associated with a line so that incoming speech actuates a locked-in flashing line lamp.

Up to this point, we have considered the features and operation of the 300 System as related to the controllers in an air route traffic control center. Although the supervisors have equipment which operates in a similar manner to the controller's equipment, their consoles have some special features. For example, they have direct-access line keys and lamps for every line in the system. This gives them a constant indication of the status of all lines and rapid access to all of them. A measure of added security is provided by giving the supervisors' positions independent facilities for connecting to the lines by direct access. Instead of using the crossbar switch field and common-control equipment, the supervisors connect to the lines by a circuit operating on a relay-per-line basis.

Although the 300 System is essentially for telephone communication, it does have a radio-transfer feature. Some of the controllers have switching equipment owned by the Federal Aviation Agency for connecting to air-ground radio transmitters and receivers. The controller uses the same telephone set for radio as for telephone communication. Normally, he is connected to his radio-control equipment until he operates a line key, the indirect-access key or common-answering key. By operating one of these keys he automatically transfers his telephone set from radio to the 300 System. When he releases the line in the 300 System, he returns to radio.

By request of the Federal Aviation Agency, Bell Laboratories has undertaken the development of radio-switching facilities as part of the 300 System. This will result in a fully integrated system including such features as preselection of combinations of FAA radio channels by use of the pushbutton dial. At present, the standard 300 System does not include radio switching, but it is included in an installation at the Federal Aviation Agency's Bureau of Research and Development Center near Atlantic City, New Jersey, where it is being evaluated.

The Federal Aviation Agency is now carrying out a general program of changing over to the 300 System. Four installations are in operation in air route traffic control centers at Fremont, California; Hampton, Georgia; Oberlin, Ohio; and Hilliard, Florida. The successful performance of the No. 300 Switching System in these centers exemplifies the results of close cooperation between the Bell System and the Federal Aviation Agency in resolving the many communication problems of air traffic control.

The watch supervisor is responsible for the overall operation of the control room. He has access to all lines within the air route traffic control center.

The design of any telephone equipment is always complete and never final. The 608A PBX switchboard, recently designed at Bell Laboratories, is a departure from tradition that results in a new versatility for an old and service-proven Bell System device.

O. C. Olsen and J. G. Walsh

A Pushbutton PBX Switchboard

Design criteria for a private branch exchange (PBX) switchboard are defined by the nature of the traffic it handles. The similarity of this traffic in most business firms and institutions establishes standard basic operating requirements for any PBX. The logical next steps in the design of a new PBX are toward better service for station users, easier operation for PBX attendants, and greater flexibility to handle different requirements of different users. These should be coupled with the always desirable quality—improved appearance. Easier operation is a major factor which, upon close scrutiny, becomes part of the larger area of human factors.

Many PBX attendants are "doublers in brass" who serve their companies as receptionists and information clerks as well as switchboard operators. A switchboard allowing quick, almost "second nature" operation frees the attendant from preoccupation with technical procedures so she may concentrate on a calling party's request. To help fill these needs, Laboratories' engineers designed the 608A PBX for pushbutton operation. This article describes the operation of this switchboard and its new design features which, combined with the best features of existing switchboards, results in unusual flexibility and a design that encourages improved service.

Its appearance immediately sets off the 608A PBX from its forerunners. A low silhouette—a desirable characteristic in modern industrial design—is achieved with little sacrifice in line and trunk capacity. A fine integration of esthetic and practical design was attained by sloping the jack field toward the back of the board and the keyshelf downward. These slopes enhance the very modern lines of the board and result in a more comfortable operating position for the attendant.

The modern theme was carried into finish and color. The casing, composed of removable panels, is usually painted with textured vinyl, either beige-gray or medium-gray. The jack field and keyshelf, are a contrasting light beige-gray, a pleasing departure from the black of older boards. A customer who wishes to match a particular decor can order the board with unfinished panels

The 608A PBX switchboard is shown here in a three-position multiple arrangement. Each operator's position can be supplied as a single section.

and paint them as he likes. The panels' construction—a unique sandwich of thin outer layers of aluminum with a corrugated cardboard core—is light but very strong and it lessens relay noises from inside the board.

Another advance in switchboard design which yields greater comfort for the attendant is achieved by a novel cord-weight arrangement. Previous boards were either placed on a 6-inch platform or used a double-pulley cord weight to gain space for the long cords required by a multiple board. The platform necessitated a special, higher chair for the attendant; the double pulley was cumbersome. The 608A circumvents either arrangement with a guided-cord weight that rides up or down on a guide rod as the attendant pulls or releases the cord. The rod limits side-to-side movement and guides the cord at an angle toward the back of the casing. This allows longer cords and permits the weight to drop almost to the floor without loss of toe room for the attendant. This arrangement keeps the front of the keyshelf at ordinary chair height and lets the attendant manipulate the cords easily.

Basically, the 608A is a manual cord switchboard for connecting between central office trunks and inside stations, or between stations. Alternatively, it is used as an attendant's position for a dial PBX, the 740E or 701B, for example. The great flexibility of the 608A PBX stems from the fact that with slight modifications it can be adapted to varying traffic conditions. Although the nature of traffic to all PBX switchboards is similar, the volume differs greatly, and it may increase with the customer's business. Some PBX boards are easily handled by one attendant. Others, with hundreds of trunks and thousands of stations, may need as many as twenty.

A customer's choice of a switchboard has generally been determined largely by the volume of traffic. Often, a significant increase in traffic dictates a change to a switchboard with greater capacity. Thus, Operating Companies are faced with the difficult problem of deciding upon the type of switchboard to be installed initially. The new switchboard neatly solves the problem because it plays a dual role as the volume of traffic directs; it may be a single-position board, or a multiple switchboard with any number of positions as shown in the photograph on this page. This is another unique design feature that deserves attention.

The keyshelf of the switchboard section has space for 16 cord pairs. The pushbutton keys and lamps associated with the cords are contained in plug-in units. The relay units for the cords—also plug ended—are installed on shelves inside the board. Additional key and cord units are merely plugged in to meet changing traffic conditions.

The number of station lines is also easily increased. The jack face opening on the basic switchboard is 11½-inches high—sufficient space for nonmultiple and medium sized multiple boards. The jack mountings, which are not as high as on older boards, and the combined lamp and designation strip—rather than a single strip for lamp and another for designation tags—are an example of effective use of space on the new board. For very large multiple boards extension bars are spliced to the framework and the position roof is raised. This increases the jack face opening to 19½ inches and jack strips can be added as they are needed in the additional space. The printed labels with adhesive backing used in the stile strips and the paper forms for designation strips are easily replaced for new or changed numbers. The table on page 163 is a concise summary of the switchboard's capacity and the range of its utility.

For the 608A PBX, the final test of many of the new design features we have discussed lies in how they contribute to the central idea—simplicity of operation. All areas on the compact

board are easily reached. The keyshelf—a one-piece aluminum die casting—contains mounting space for the keys, a transparent bulletin holder, a metal ticket clip, a dial, and the cords. In front of each cord pair are two supervisory lamps and a single pushbutton that replaces the lever-type keys on older boards.

To answer a call the attendant selects a cord pair and presses the TALK pushbutton which then lights. Her headset is connected through the position circuit to the cord by a relay in the cord circuit. She plugs the rear cord into the jack of the calling line or trunk and completes the connection by plugging the front cord into the called line or trunk. On calls to stations, ringing starts automatically and the supervisory lamp winks periodically until the phone is answered. The attendant presses any other TALK button to be released from one cord pair and connected to another or presses the common RELEASE key to disconnect her telephone set from the cord pair.

The pushbuttons are nonlocking. This feature, operating jointly with an electrical interlock chain relay circuit, saves the attendant the bother of restoring keys to "normal" which is necessary on switchboards with locking lever keys. Further freedom from mechanical details is gained because all calls, trunk or station, can be answered with the rear cord and completed with the front cord. On most older boards trunk calls had to be answered with the front cord and station calls with the rear.

Calls from a station to an outside line over a central office trunk may be dialed either by the station user or by the attendant. If the station user dials, the attendant plugs the front cord into a trunk jack and pushes a THRU DIAL button which connects the station directly to the trunk and releases her from the connection. If the attendant completes the call she plugs the front cord into the trunk jack and dials.

Another new idea in the 608A PBX is designed to improve service for the calling party on calls from a central office. On other boards, the attendant trips the ringing on calls from a central office when she plugs a cord into the trunk jack. If she is attending to other tasks and does not operate the TALK key immediately, the calling party no longer hears ringing. In the 608A PBX the attendant may plug into the trunk jack at any time but ringing continues until she presses the TALK button and comes into the circuit. The supervisory lamp flashes as a reminder that a call is waiting and continues to flash until she answers.

Special Signaling Devices

If the attendant leaves the board or is momentarily distracted by another task, she turns on an AUXILIARY SIGNAL key. If a call comes in or a cord supervisory lamp lights with this key on, a tone signal is generated by a transistor oscillator which feeds a small loudspeaker. This is as effective as the usual buzzer, a more pleasant sound and the volume is easier to control. The tone is stopped automatically when the attendant answers the call even if other lamps are still lighted. Many other boards have a foot switch to silence the buzzer.

The new board has other useful signaling devices which in the past were a feature only on large switchboards. For example, the station user does not have to jiggle the switchhook continuously to signal the attendant; he merely presses it once. The supervisory lamp flashes as a recall

608A PBX—LINE AND TRUNK CAPACITY

Type	Manual Switchboard		Dial PBX Attendant's Position	
	Station Lines	Trunks	Station Lines	Trunks
Nonmultiple	360	80	300	80
Three-Panel Multiple, Board—48 inches High	560	120	900	180
Four-Panel Multiple, Board—48 inches High	800	160	1200	240
Four-Panel Multiple, Board—56 inches High	1600	160	2400	480

signal to the attendant. The flashing is accompanied by an audible clicking or a tone signal controlled by the auxiliary signal key.

Among other operating features worth mentioning are nonlocking SPLITTING and DIAL BACK buttons. The attendant pushes the SPLITTING button to exclude a calling party from the circuit while announcing the call to a station. The station user can thus talk to the attendant without being overheard by the caller. The DIAL BACK button permits the operator to transfer the dial, normally associated with the front cord, to the back cord. When these buttons have been operated the circuit may be restored to normal merely by pushing them again. The circuit is automatically restored when another TALK button or the RELEASE button is depressed. A TRANSFER key allows the attendant to connect her headset to a vacant adjacent position. Other pushbuttons permit her to ring manually on the front or back cord, to make a peg count, and to connect to a paging circuit.

The cord circuit is arranged for "delayed thru supervision", that, when the station user hangs up, automatically frees the central office trunk for incoming calls after a short delay. During this delay the station user may depress the switchhook and recall the attendant at the board without disconnecting from the central office.

A number of other features—not so apparent visually—are of great benefit to the PBX customer. Because the 608A is a universal switchboard adaptable to various sizes of offices and to differing traffic conditions it is possible to manufacture it on an assembly-line basis. Thus the basic board and additional plug-in units can be stocked and the customer receives delivery of his switchboard soon after he orders it.

Factory wired multiple cables with solderless wrapped connections are used—another unique feature in switchboard design. These cables use 26-gauge wire which make them lighter and more flexible. Further, they require less ironwork for supports than older multiple cables.

Maintenance of the board is made much easier by virtue of the plug-in units. Defective units may be removed for repairs and replaced immediately with another unit. Cord seats, long-wearing nylon pressed into the die-cast key shelf, also are easily replaced; they are merely pushed out and replaced with new seats.

New pushbutton switchboards are in service at several industrial offices. High praise from customers and from operating companies has supported Bell Laboratories new approach to an old and honored Bell System service.

New Superconducting Ductile Alloys

Two related discoveries that will have important implications in several scientific fields were announced by Bell Laboratories scientists to the Spring Meeting of the American Physical Society last month. One was the discovery of a series of new ductile superconducting alloys; the other, that several other ductile alloys will remain superconducting in extremely high magnetic fields. These discoveries may greatly simplify the problem of making superconducting electromagnetic coils.

B. T. Matthias described new alloys made of molybdenum and technetium (a man-made element) which become superconducting at temperatures higher than for any other ductile alloy. Cryogenic experiments showed that an alloy of molybdenum-technetium is superconducting at temperatures near 16 degrees K. A brittle alloy of niobium-tin, Nb_3Sn, discovered by Mr. Matthias in 1954, has the highest known transition temperature of any superconducting material (RECORD, *March*, 1961).

The second development was described by J. E. Kunzler. He discussed low-temperature experiments with a compound of niobium and zirconium that remained superconducting in a field of 80,000 gauss. Other alloys, niobium-titanium and vanadium-titanium were found to be superconducting materials at liquid helium temperatures.

The new alloys will complement the application of Nb_3Sn. Extrapolation of data from experiments on Nb_3Sn at temperatures between 14 degrees K and 18 degrees K indicate that this material will remain superconducting at temperatures around 4 degrees K in fields of 200,000 gauss and possibly higher. But Nb_3Sn is very brittle and special metallurgical techniques are required to form magnet coils that can withstand the mechanical forces produced by very high fields. The discovery of the more ductile superconducting alloys gives promise of simplifying the problem.

A superconducting electromagnet will make large magnetic fields available for study. These fields can extend the operation of many electronic communication devices to higher frequencies, thus providing increased bandwidth for radio-relay communication systems.

Another attractive application is in the field of thermonuclear fusion for the production of electric power. High fields are needed as "magnetic bottles" to contain high temperature gas plasmas.

A slight fault in a waveguide may ruin high-power microwave signals. The Laboratories has developed tests that detect these faults in waveguide circuits that may be used in our defense radar systems.

T. E. Mardis

Techniques for Microwave Breakdown Measurements

For almost 30 years the Laboratories has been concerned with perfecting that empty metal "pipe" which is so vital to microwave transmission—the waveguide. There are many reasons for this continuing concern.

Basically, a faulty waveguide may be the weak link in the chain of a microwave system. Any slight imperfection on the inner surface of the guide sets up disturbances that can make a noisy hash of signals passing through. Precise design and manufacturing techniques have minimized this problem, however; in present microwave systems, waveguides carry and contain radio waves as effectively as a lead pipe contains water. But as the microwave art advances, waveguide components must often be redesigned to operating requirements above those of previous assemblies, and the new waveguides are often more complex than their predecessors. This complicates the problem of determining whether a specific section of waveguide will perform within the operating limits specified in its design.

For example, military radar systems took a great step forward with the development of the magnetron. A source of extremely high levels of microwave power, this generator effectively extended the vision of these systems, but it raised the question of how much power a waveguide could carry. To answer this it was necessary to define the point of peak breakdown power in any waveguide assembly. This proved to be an elusive parameter that largely defies accurate calculation.

The major difficulty is not that mathematical analysis fails but that as waveguide components become more complex they become more susceptible to electrical phenomena that may impair transmission, and the same complexity makes me-

chanical and visual inspection of the inner surfaces almost impossible. Consider, for example, the inseparable problems of impedance matching and standing waves.

At points in a waveguide run where there are changes in impedance, energy is reflected and creates standing waves. These reduce the power-handling capacity of the guide (see the graph below) because the voltage at the peak of a standing wave is greater than the voltage that would exist in the same waveguide without standing waves. A straight section of waveguide can be terminated in its characteristic impedance so no energy is reflected. In complex assemblies—rotary joints, duplexers, feedhorns and the like—perfect impedance matching over a band of frequencies is almost impossible to attain. In addition, although mechanical and visual inspection is easy for straight sections, for complex sections it is difficult.

To put it another way, the best geometry for a waveguide may be determined by mathematical analysis, but, if in manufacture, a corner radius is not properly made, it creates a point of high voltage stress which was not a factor in the mathematical model and which reveals itself only under actual operating conditions. Too often it would reveal itself in microwave breakdown. All this shows the need for some sort of electrical tests to ascertain, with a large measure of certainty, if a waveguide will deliver the performance that was designed into it.

Measuring Techniques

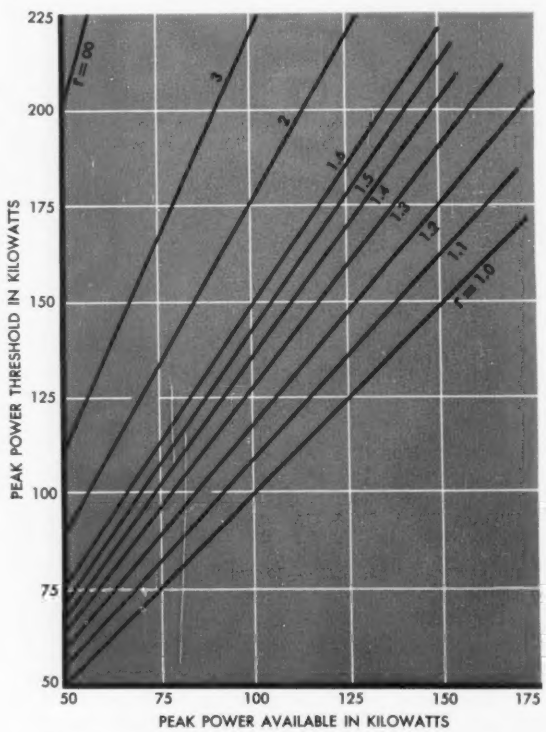
To solve this problem the Laboratories developed techniques for measuring microwave breakdown in a waveguide under the actual load it was designed to carry. This is done by using, usually, a magnetron as the source of the high level of power the tests need. This source of power is of major importance.

Many times the impedance match and insertion loss of a high-power unit have been well within their requirements in a low-power test; when the waveguide was operated at the high-power level of a magnetron it failed to carry the power. This can be explained in terms of the mechanics of the breakdown phenomenon which is, in effect, the ionization of a localized region of air.

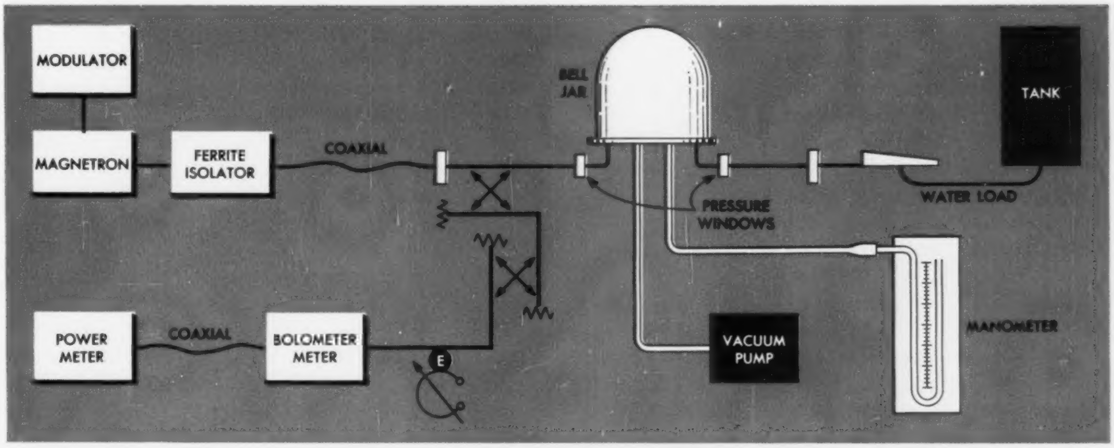
Ionization results from the collisions among molecules, free electrons and ions in the air in a waveguide. Normally these collisions are completely elastic. That is, there is no transfer of energy and the air is not ionized. However, in a high-power waveguide both the microwave electric field and photons of radiation (always present in the form of emission from radioactive material, X-rays and cosmic radiation) supply the energy for ionizing collisions.

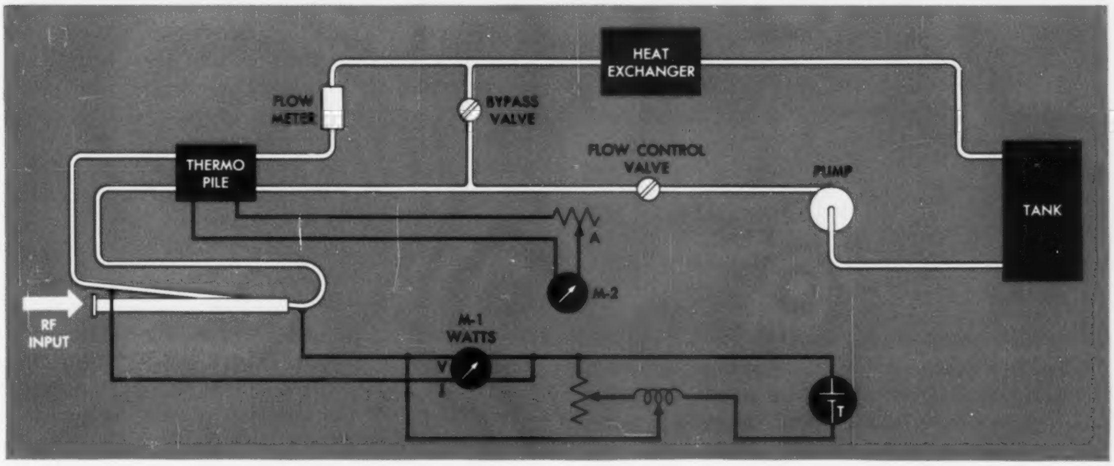
This very brief note on the mechanics of the phenomenon of breakdown in a waveguide helps to clarify an intriguing problem that presented itself early in the program of breakdown study. If, for example, a waveguide tested at 200 kilowatts of peak power for 15 minutes showed no breakdown it would seem safe to assume that it could handle this amount of power. Then what would explain the fact that the same test run on the same component several hours later would result in breakdown in a few minutes?

Chance alone will produce an ionizing event—in the form of additional energy supplied by photons of radiation from natural sources—simultaneously with the short pulse period of the microwave energy supplied to a waveguide. But unless this happens there is no ionization. To wait for radiation from natural sources to ionize the air in a waveguide is too much of a random technique to be used in a test of this sort. A



In this graph, which shows the effect of standing waves on the power-handling capacity of a waveguide, "r" denotes voltage: standing wave ratio.





Top part of the drawing shows, schematically, the equipment used in making the high-power tests which are described in this article. The lower part is a schematic of the water load test set.

practical solution to this problem is to irradiate the unit under test by placing a radioactive source—usually cobalt—close to the waveguide. With this constant source of radiation, the test does not depend on the chance occurrence of a photon of radiation from natural sources to create the conditions necessary for breakdown.

Two distinct effects characterize the phenomenon of breakdown. The first—corona—appears as a glowing region of ionized air. Corona reduces transmitted power and increases the input standing wave. Corona is difficult to detect because in this case it does not usually generate an audible noise, and it is generally not possible to look into a waveguide under test. The second effect—which occurs at complete breakdown—is the formation of a continuous arc, accompanied by a loud "singing," across the waveguide. It is easily detected by the noise and because it reduces transmitted power to zero. This effect is a valuable indicator of breakdown during the course of an actual test measurement.

The heart of the equipment used for making these measurements (*see drawing on this page*) is the water load. It consists of an RF head, a water circulation system and a calibration circuit. Its value is that it makes possible considerable accuracy in measuring high levels of microwave power.

The unit pumps water through a tube inserted in the RF head and the water temperature rises as it absorbs the RF energy. The thermocouple measures the differential between input and output temperatures. The temperature of the water depends only on the value of average RF power. This value is converted to peak power which, of

course, defines breakdown. For example, if a waveguide is tested at 200 kilowatts of peak power with a 1 microsecond pulse repeating at 1000 pps, the water-load test set would register an average power of 200 watts.

An actual test—for clarity let us assume a test on a double-ended waveguide component, say, a rotary-joint—is made according to one of two procedures. In the first method the power level is kept constant and the frequency is swept slowly from one end of the band to the other. This method is not used too often because it necessitates the use of a motor to drive the magnetron across the band and raises the rather complex problem of maintaining a constant power output. The second, more usual, method is to make a test at ten or fifteen equally spaced points across the band, testing each point at least three minutes. The test is made at a predetermined power level and frequency, and all that is required is to listen for the singing of arc-over and to watch the output power meter for a reduced reading that may indicate corona.

False Breakdown

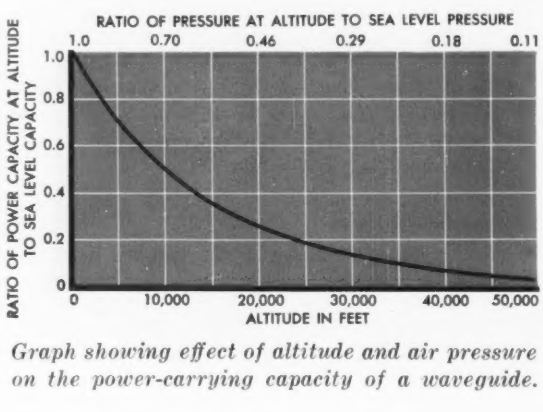
Sometimes a false condition of breakdown, known as "spitting," occurs. The guide breaks down, but the arc disappears after a few "spits." Dust or dirt particles which rapidly burn out in the waveguide can cause this. However, if this type of breakdown occurs the inside of the guide is flushed with fresh air before power is applied again. Many tests indicate that ionized air in the guide after any breakdown reduces its power handling capacity. A high-current arc, if maintained for any length of time, can pit and burn the inner surface of the guide. To prevent this, power is immediately reduced when breakdown occurs.

Normally, breakdown measurements are made with a magnetron as the power source. It is, however, often desirable to determine a waveguide's ability to handle a higher level of power than a magnetron or any other high-power source can supply. One reason for this is fairly obvious—it defines the margin of safety built into a unit. A second, perhaps more cogent reason, is that frequently new waveguides are designed concurrently with a new power source and the power requirement may exceed that of any existing generator. This higher power can be obtained, in effect, by taking advantage of the properties of one parameter of breakdown—air pressure in a waveguide.

The power-handling capacity of a waveguide depends on air pressure, increasing as the air pressure is increased, decreasing as it is reduced. High power can, therefore, be simulated by maintaining normal magnetron power output and at the same time reducing the air pressure in the guide. This produces the same test conditions and voltage stresses in the waveguide that would exist if the air pressure were maintained and the magnetron power output increased.

This method is, however, only valid in air-filled parts of the waveguide. Any part of the guide that is filled with a solid dielectric would receive only the peak power output of the magnetron. For example, if the magnetron has a peak power output of 200 kilowatts and it is desirable to test the waveguide at 300 kilowatts, the air pressure inside the guide could be reduced to simulate the higher input. However, if at one point the waveguide is completely filled with a dielectric plug, this plug would receive only the 200 kilowatt input from the magnetron. If the section beyond the plug is again filled with air the simulated conditions prevail there. The method is quite pertinent for tests of airborne waveguide components which operate at the reduced pressures of high altitudes. The graph below is a theoretical curve showing the effect on the power-handling capabilities of a waveguide as operating altitude is increased or air pressure in the waveguide is reduced.

It is often necessary to make breakdown tests on single-ended waveguide components such as antennae or feedhorns. There are two problems which are unique to components of this type. The first raises the question of how to monitor the level of test power because a feedhorn cannot be terminated in the water load. This is solved by calibrating a directional coupler and a power meter against the water load. The second problem—how to dissipate the high-power energy radiating from a feedhorn—is actually not within the scope of this article. It concerns the danger high-power microwave radiation holds for people



Graph showing effect of altitude and air pressure on the power-carrying capacity of a waveguide.

The author, T. E. Mardis, is shown calibrating a torque-vane wattmeter while making breakdown measurements on a section of waveguide. Rotary joint in the bell jar is being tested.

working close to high-power densities. Therefore, it is sufficient to remark that the dangers are well known and proper safety measures have been thoroughly charted.

In the art of microwave breakdown measurements, as in other techniques, the desire for greater precision has stimulated the investigation of new devices. A recent development is the torque vane wattmeter (*see photograph on this page*) which has an accuracy of about 2 per cent over the 8.5 to 9.6 gigacycles per second frequency band. This instrument is considered an absolute standard because its calibration depends only on measurements of mass, length and time. The torque vane wattmeter will measure power in the range of 10 to 200 watts. Because it absorbs a negligible amount of power it is not used as a combination load and wattmeter as is the water load.

Another recent development, the traveling-wave resonator, promises to improve the method of testing waveguides at levels above their theoretical peaks. In the method described above the air-pressure in the guide is reduced and power is sent to the air-filled parts of the guide. The traveling-wave resonator, however, stores energy in the form of traveling waves by injecting energy from a directional coupler into a waveguide run which forms a closed loop. As the traveling wave moves through the unit, every part of it, air filled or solid-dielectric filled, is subjected to full power.

These measurement tests, because they are performed under actual operating conditions, are a thoroughly reliable way of judging the adequacy of waveguide design. Moreover, inherent in the art of "systems" engineering—an art in which the Laboratories is eminent—is the idea that all components of a system are designed together as a unified complex. This means that waveguide circuits are as important to a microwave system as a magnetron, the transmitter, the receiver, or any other component. The breakdown tests are designed to ensure that waveguides meet their stringent requirements not only as components but as subassemblies in a vast operating system and under rigorous conditions.

Using a novel capacitance measuring technique, Bell Laboratories cable engineers devised a way to monitor the concentricity and diameter of ocean cable—physical characteristics that determine its electrical characteristics and performance.

S. Harris

A Concentricity and Diameter Gage For Ocean Cable

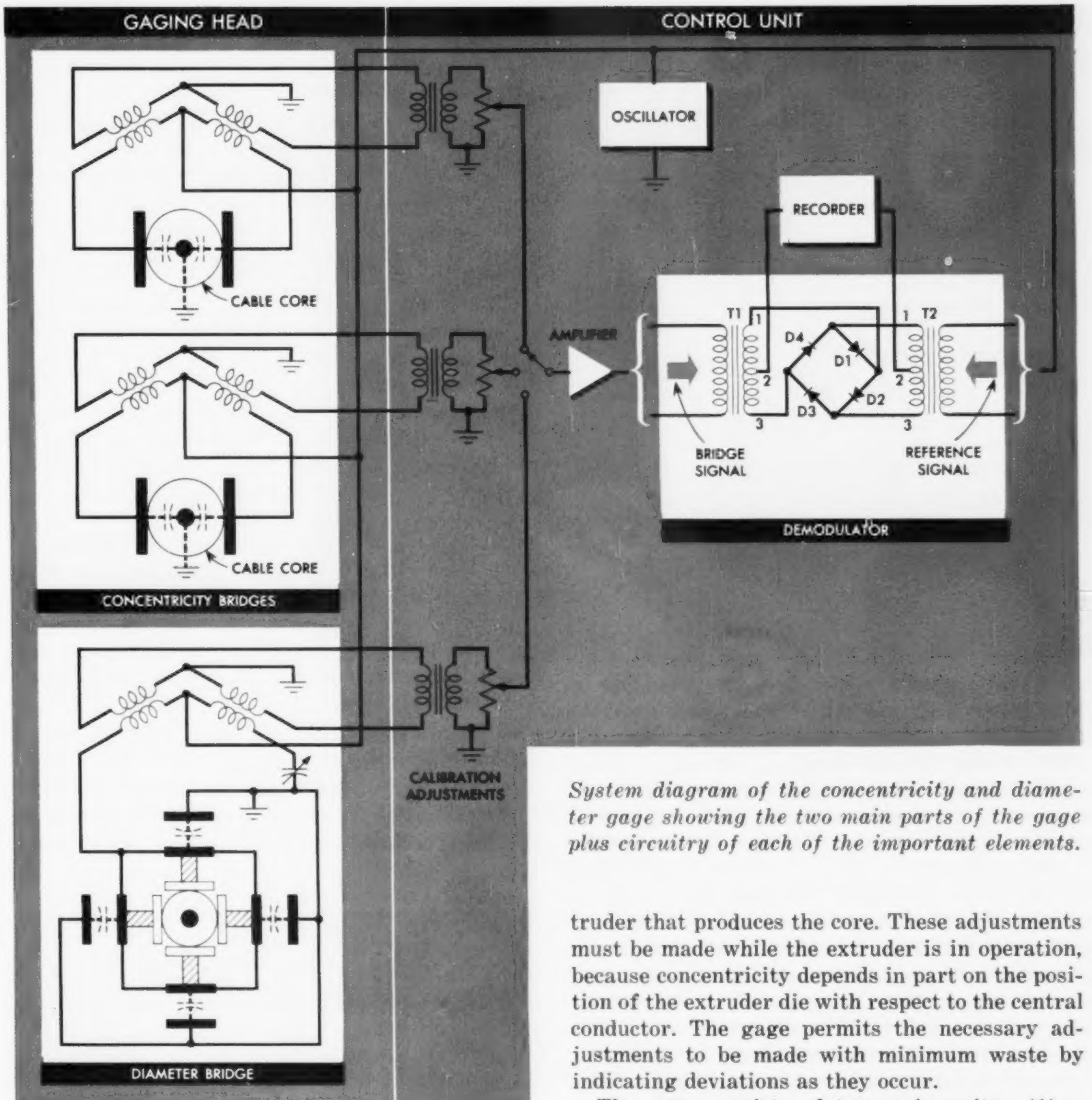
During the early 1960's, the Long Lines Department of the American Telephone and Telegraph Company plans to install thousands of miles of cable in both the Atlantic and Pacific Oceans (RECORD, *October*, 1960). This vast cable construction program, representing a Bell System investment of hundreds of millions of dollars, is perhaps the ultimate tribute to the success of the transatlantic, Hawaiian, Alaskan and Puerto Rican cables. In turn, the success of these cables is due to careful design of the system and its components, and meticulous care in manufacturing. This is especially true of the undersea repeaters (RECORD, *January*, 1959)—one of the most exacting communications components ever made.

The design of these all-important repeaters is based on the electrical parameters of the cable, so it is essential that these parameters be known accurately and that they remain constant along the entire length of the cable. The coaxial structure of the existing ocean cables is a core about $\frac{5}{8}$-inch in diameter, consisting of a copper central conductor, a surrounding plastic insulating sheath, and an outer coaxial return conductor made up of six spiraled copper tapes. The structure is then covered with tarred jute and armor wires to protect it in its underwater environment. This article will be concerned with the core of the cable.

For a central conductor of a particular diameter, the capacitance and inductance, and hence the cable attenuation, are functions of the diameter of the core and of the position of the central conductor within the core. The specification for the armored coaxial cable used in the ocean cable systems: (1) limits variations in the capacitance of the core to only plus or minus 0.0007 microfarad from the nominal value of 0.1733 microfarad per nautical mile; (2) requires the diameter of the core to be held to plus or minus 0.004 inch from the nominal diameter of 0.622 inch; and (3) limits the eccentricity of the central conductor with respect to the central axis of the core to 0.015 inch.

To insure that these requirements were met in the manufacturing process, cable engineers at Bell Laboratories designed and developed two special devices—the capacitance monitor (RECORD, *August*, 1957) and the concentricity and diameter gage.

Briefly, the capacitance monitor automatically



System diagram of the concentricity and diameter gage showing the two main parts of the gage plus circuitry of each of the important elements.

holds the unit capacitance of the core within the specified limits, regardless of small variations in the diameter of the central conductor and of the dielectric constant of the insulating material. It does this by constantly monitoring the capacitance and using the measurement to control the core diameter through a feedback arrangement.

The concentricity and diameter gage, on the other hand, detects and records variations in the eccentricity of the central conductor as well as variations in the diameter of the core. It is especially valuable in the initial adjustment of the extruder that produces the core. These adjustments must be made while the extruder is in operation, because concentricity depends in part on the position of the extruder die with respect to the central conductor. The gage permits the necessary adjustments to be made with minimum waste by indicating deviations as they occur.

The gage consists of two main units: (1) a head, through which the cable core passes, and which contains sensing electrodes and capacitance bridges; and (2) a remotely located control unit containing detection equipment and a recorder. A diagram of the relationship of these elements appears on this page. Basically, the gage works like this: The electrodes sense variations in diameter or conductor position as variations in capacitance. These variations are measured by the capacitance bridges, converted to voltages by a demodulator, and then recorded as dimensional variations on a chart recorder. The gage is designed to detect variations in diameter and conductor position as

small as 0.001 inch, corresponding to capacitance variations in the order of 0.2 micromicrofarads for diameter and 0.02 micromicrofarads for conductor position.

Gaging or sensing is actually done by the head, shown in operation on page 173. The housing consists of two hinged halves that may be opened and placed around the core. It has an electromagnetic safety release, which opens to prevent damage to the electrodes and core if an oversize section of core comes through. Within the housing are two sets of electrodes and three capacitance bridges.

Operating Principles

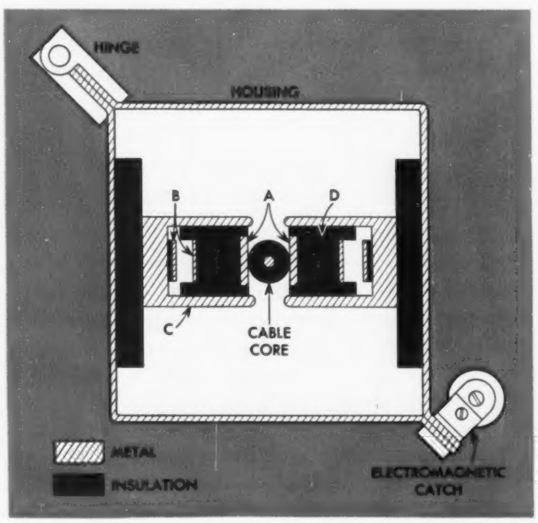
The diagram shown in the column at right is a cross-section view showing one set of electrodes. The pair designated A are stainless steel plates attached to insulating blocks, D. The blocks are free to slide back and forth within the guides, C, and are lightly pressed against the cable core by springs, which are not shown. The capacitances between plates A and the grounded central conductor depend on the concentricity of the central conductor in one plane. Two pairs of plates, designated B, form two variable capacitors that are used in measuring the diameter of the cable. A second set of electrodes, mounted perpendicularly to the set illustrated, measures concentricity in that plane.

The circuit for measuring the concentricity of the central conductor is shown in the upper left in the diagram on page 171. The capacitance between each plate and the grounded central conductor forms two arms of a capacitance bridge. An oscillator applies a signal of approximately 200 kc between the center of the transformer primary winding and ground. If the two capacitances are equal, their impedances are equal and the bridge is balanced. No signal, therefore, appears on the secondary winding. If the capacitances are not equal, as would be the case if the central conductor were physically closer to one plate than to the other, the impedances of the two branches are not equal and the bridge is unbalanced. A current proportional to the amount of unbalance is then induced into the secondary of the transformer and is fed through the amplifier to the demodulator.

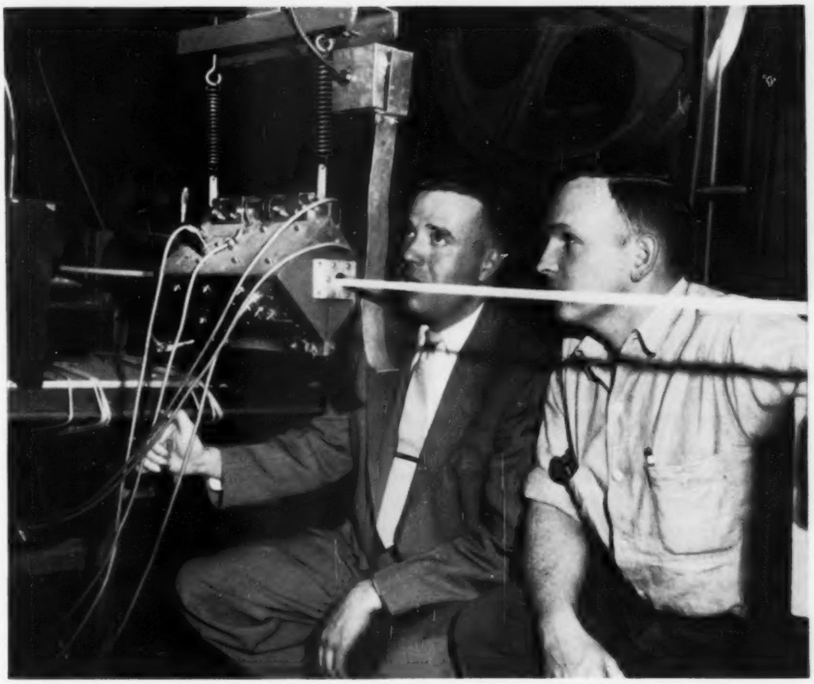
The phase of this current, with respect to the oscillator signal, depends on the ratio of the impedances in the two arms. For example, if the capacitance between the left-hand plate and the central conductor is greater than that between the right-hand plate and the conductor, current having a certain phase relation to the oscillator current will flow through the transformer. If the capacitances are inverted, the phase of the current flow will change by 180 degrees with respect to the oscillator current. The magnitude of the current flow is a function of the amount of unbalance; its phase with respect to the oscillator current is a function of the direction of unbalance. In other words, the magnitude of the current indicates how much the central conductor is off the center axis of the core, and its phase indicates in which direction it is off center.

A second set of electrodes measures the concentricity in a plane 90 degrees from that of the first set of electrodes. By switching from one set of electrodes to the other, the concentricity of the central conductor can be measured in two planes.

The operation of the "B" plates *(see diagram below)* in measuring the diameter of cable is shown schematically at lower left in the diagram on page 171. All four sets of electrodes connected in parallel are used for this operation. The capacitance between the movable plates and the fixed plates varies with the diameter of the cable core. If the core increases in diameter, the movable plates move closer to the fixed plates and the capacitance between them increases. The capacitance is balanced against the variable capacitor in the bridge circuit, which is set to balance at the nominal core diameter of 0.622 inch. Variations in the diameter of the cable core cause a corresponding unbalance in the bridge, with a resulting current appearing in the secondary



Cross-section view of gaging head showing location of coaxial core and inner construction of gage.



Guy Walters (left) of Bell Laboratories and Orland McPherson of Simplex Wire and Cable Co. inspect gaging head during manufacture of Bell System cable at Simplex.

winding and hence at the demodulator. As in measuring concentricity, the magnitude of this current depends on the *amount* of change in diameter and its phase on the *direction* in which the diameter varies from the nominal diameter of the core.

Because of the electrode arrangement, the position of the core has no effect on the measurements of diameter—that is, the core does not have to be perfectly centered with respect to the electrodes An increase in the capacitance between one pair of plates, brought about by the core moving toward one side of the housing, is compensated by a corresponding decrease in capacitance between the plates of the opposite electrode. Actual variations in the diameter of the core, however, do result in a net increase or decrease in separation of all four pairs of plates and hence a net change in the capacitance measured by the gage.

The control operator can select which of the three measurements he wants to record by means of a switch on the control panel. The signals are then amplified and applied to a "ring" demodulator in the control section, shown at the right in the diagram on page 171.

The demodulator is similar to those widely used in carrier telephone systems for separating voice signals from carrier signals and is sensitive to changes in both the magnitude and polarity of current from the measurement bridges. Thus, engineers monitoring the chart record can spot not only variations in the core diameter and conductor position but also the direction of these variations.

Two standards that simulate cable cores of specific diameter and eccentricity are supplied with each gage for calibrating it. These standards are made of short sections of polystyrene rod cemented together over a stainless steel central conductor. One standard has a diameter equal to the nominal diameter of the core and an eccentric central conductor. The other standard has a diameter greater than the nominal value and a concentric central conductor. The gage has adjustments so that it may be calibrated from the known dimensions of the standards.

The concentricity and diameter gage is another example of the many unique tools and processes that were devised to insure the high-quality, reliability and long life of Bell System ocean cable systems. It was used successfully in the manufacture of undersea cable for the first two transatlantic cable systems, and is still being used to check the electrical characteristics of ocean cable for certain underwater military communications systems.

A telephone operator at a central office is confronted by an ever-changing pattern of lights and signals. To train her quickly and efficiently, Bell Laboratories has developed improved . . .

J. J. Mosko

Operator-Training Equipment

Telephone operators can be trained on any of several training units. In some companies, they are trained at switchboards that are normally part of the central office. This method, known as "inboard training," is not entirely satisfactory because it limits training periods to times when the switchboards are not needed for regular traffic.

Some companies use portable training sets for simulating practice calls, but this method also requires the student operator to sit at a regular switchboard. In recent years, the increasing volume of toll traffic has considerably reduced the effectiveness of these training methods. It became apparent that the Operating Telephone Companies needed separate operator-training equipment.

In 1951, Bell Laboratories prepared information drawings for separate toll training facilities. This enabled the Operating Telephone Companies to make their own training sets and helped, in some degree, to overcome the shortage of available training positions. This equipment was known as "energized photographic training equipment" because full-scale photographs of the switchboard jack field were fastened to the framework of a simulated switchboard. A few jacks and lamps mounted on the photographs enabled a student operator to become accustomed to making connections for several kinds of calls.

Although this arrangement took the student operator away from a position at a working switchboard, it had several disadvantages. Because the equipment was special, is was expensive. Because it was continuously in use and not as well constructed as a standard switchboard, it required considerable maintenance; and because it contained only a small number of jacks and lamps, the trainee had little notion of what it was really like to operate a working switchboard where there is an ever-changing pattern of lights. These were the prime factors that led to the development of today's energized, permanent, operator-training equipment. This article describes this new system and the particular facilities provided by it.

The various call conditions simulated by this equipment definitely decrease learning time and increase working efficiency. The automatic reaction of an operator to signals at her switchboard is acquired fastest by going through the physical motions many times; for this reason, training drills are highly important.

In a typical training program, an experienced control operator and two trainees occupy the three-position training unit. The control operator sets up practice calls by following instructions on program cards mounted on her key-shelf. The drills on these cards vary with the type of cen-

tral office that the operators are being trained for and cover most conditions that may be encountered in actual work at a switchboard. The control operator acts as the "calling party" on originating calls and the "called party" on calls completed by the student. She simply operates certain keys to simulate calls, to pass orders, or to signal to the trainees.

When the control operator plugs in her telephone set, the battery-supply relay is operated, energizing the training unit. By means of a talking-monitoring key at the control position, she may talk and listen to one student while listening only to the other and reverse the procedure to talk to the other student when necessary. Student operators can call the supervisor to ask her help in a problem, or, should a call come in for the supervisor at a student position, the supervisor can take such calls at that position.

Training periods last for 10 to 15 days, depending on the type of central office. Approximately 35 per cent of this time is spent at the practice switchboard. The remainder of the training time is spent in classroom discussions of the equipment and the problems involved in operating the switchboard.

Since the demand for training equipment is primarily for toll and dial systems assistance switchboards, the development was limited to these switchboards. However, the circuits were made similar to those required for many other types of switchboards; thus, this equipment also serves as a pattern for other training units that can be manufactured locally to meet individual requirements.

The energized, permanent, operator-training unit consists of three switchboard positions: one for an experienced control operator, the other two for student operators. Still another position is available for adding jack-field panels to simulate a seven-panel multiple-jack arrangement, or for use as a separator between two training units in a lineup.

The lower section of the control position contains all of the circuit equipment for a training unit; the equipment for the student positions is

Two student operators respond to training signals originating from the control operator at right.

in the lower section of each of those units. All three lower sections are completely shop-wired. When the unit is installed, only the battery-supply leads and the signal and tone supplies need to be wired to the unit and the interconnections made between the three positions.

Two basic types of telephone trunks go to each position: one type simulates incoming calls at the trainee's position and is known as an originating trunk; the other, used by the student to complete calls, is known as a completing trunk. A training unit has 20 originating and 20 completing trunks. Because the trunks terminate on keys at the control position, this unit is a distinct improvement over the inboard training equipment which terminates the practice trunks on jacks and consequently requires considerable cord-handling by the control operator to originate practice calls.

On the face of the training unit, each of the three panels in the practice position has two strips of completing trunk jacks and associated lamps. Each strip consists of 20 jacks or lamps. However, only every other trunk jack and lamp, and only every fourth answering jack and lamp, are wired. Thus, for each panel, 20 energized trunk jacks and 10 energized answering jacks are available. The additional space in the jack field may be filled with dummy apparatus or reclaimed jack, lamp, and designation strips.

Training Facilities

The location of the jack and lamp strips simulate a working switchboard arrangement. These strips are cabled to terminal strip where the jacks and lamps are interconnected. This simplifies the installation and facilitates assignments of trunks to jacks. It also permits relocation of jacks and lamps within the panels, and permits relocation of the training unit with a minimum of wiring effort.

In addition to the trunk control keys, the control operator has other keys that she can use to set up certain call conditions at the student operator positions. A dial key or keyset-delay key permits her to indicate a send-busy condition and thus delays a student from dialing or keypulsing. By releasing the key, which lights a pilot light in the student position, she notifies the student that dialing or keypulsing may commence. There is also a coin-signal tone key that transmits simulated coin "chimes" to the trainee.

The control operator has signal cords associated with each completing trunk which she can plug into a jack and transmit audible ringing or order tones to the student. With these signal cords she can also transmit the normal signals

The controlled practice card (on left) indicates the various signals the control operator should send to the trainees. With this equipment she can simulate both "calling" and "called" parties.

associated with switchboard operation (such as "line busy," "no circuit," and re-order conditions) and can also transmit recorded announcements that notify the student of circuit delays or changes in customer numbers.

A lamp-group control key enables the control operator to shift a trunk to different jacks and lamps at the student position. In this way, she avoids repetition of a fixed pattern and the student is confronted with realistic operating conditions. To familiarize the trainee with differences in speech levels resulting from medium and long transmission lines, there is a transmission-reduction arrangement which inserts simulated transmission losses for these conditions. Pilot lamps in the control position inform the control operator that a student is dialing, keypulsing, monitoring a call, or performing a coin-collect or refund operation.

The energized, permanent, operator-training equipment offers many advantages over other methods of operator training. The self-contained unit is easily installed or relocated. The layout of equipment can be the same as that on particular standard switchboards. Key-ended circuits greatly decrease the amount of cord-handling required by the control operator with inboard training equipment. Detailed engineering usually required for ordering and establishing training facilities is reduced to a minimum. Most of all, this equipment will help train operators in less time to do a better job than any other available means. It is a development aimed at helping to alleviate the operator-shortage problem.

To avoid failures in operation on one of its complex machines—the experimental Electronic Central Office—Bell Laboratories relies on an automatic tester that checks the characteristics of each transistor used.

G. M. Lowry

Testing Transistors for the Electronic Central Office

The experimental electronic central office developed at the Whippany location of Bell Laboratories uses a large number of semiconductor circuits. The greatest concentration occurs in the central control section of the system (RECORD, *February*, 1960). This is the data and information-processing center of the electronic telephone central office. Central control employs about 43,000 diodes and about 6000 transistors. These semiconductors, and other electrical components, are mounted on printed boards which are easily removed for servicing.

Transistors are used both to maintain signal levels through "chains" of logic and to drive other circuits. Transistors also serve as signal inverters, emitter followers, pulse stretchers, and core drivers; to regulate power supplies, and to generate tones. To ensure that each transistor will perform its required circuit function in the system, an adequate testing program is required to measure the performance of each transistor prior to its installation in the system. Moreover, periodic re-tests of installed transistors and tests of transistors that have failed may provide information useful to designers of the semiconductor devices and of the system circuits.

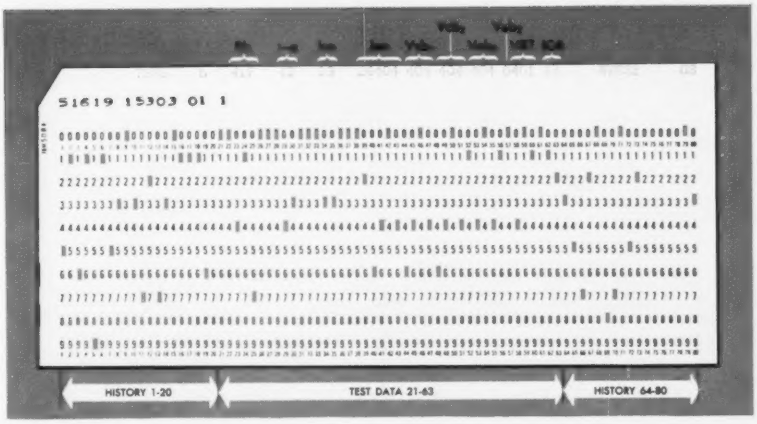
To meet this need, Bell Laboratories engineers designed and built an automatic transistor tester which has been in operation at the Whippany Laboratories since 1956. This apparatus tests each transistor and records the test data directly on punched business-machine cards. These cards contain information in a form suitable for processing on high-speed, automatic computing equipment. The operations include comparing the data on each card with standard data. This accomplishes two things: (1) it separates the rejects from the acceptable units, and (2) it keeps the recorded data available in a convenient system for purposes of filing.

The testing equipment, shown in the photograph below, is mounted on standard racks and consists of two crossbar switches, several selector switches, and a digital voltmeter. Two 100-socket matrices are available for individual transistor testing, and a 100-connector socket matrix permits the testing of transistors mounted on printed boards. A special plug-in board also is used to measure up to one hundred diodes in sequence.

The digital voltmeter in the automatic tester acts as the detecting device for the system. It presents for each test an instantaneous visual reading of the output voltage which is punched on the cards. This detector, essentially a high-impedance, dc voltmeter with electromagnetic switches controlled by servos, measures voltages to an accuracy of 0.1 per cent in one second. It has ample capacity, since it can store at one time six items of information—four digits, a decimal point, and a voltage polarity.

In typical operation, an operator conducting the test first inserts numbered transistors into the array of 100 numbered sockets. He also places correspondingly numbered machine cards, in sequence, in a "hopper." A crossbar switch, which can connect any one of the 100 units to the test mechanism, is then set so that the machine is ready to test the first transistor. After the opera-

Mrs. Margaret Goldstein, inserts group of power transistors into test sockets of automatic tester while the author readies punched cards for recording information on the transistors for ECO.



Each component tested has dossier in form of punched card. Columns 1-20 describe status of a transistor; columns 64-80 describe its environment. Columns 21-63 record electrical characteristics of devices, obtained from tester.

tor pushes the start button, the machine will automatically apply seven tests in sequence to each transistor.

At the end of each of the seven tests, a socket number is punched on the card to show that the tests were applied to a particular socket, thus affording a check on the transistor and card-numbering system. The tester applies the seven tests to an empty socket even if a transistor is missing and punches the card for that socket. It takes about one minute to test each transistor automatically, including the card punching.

Card Storage

The punched cards, one for each transistor, permanently store the results of the tests. This card system is well adapted for test data on transistors. This is because it has the capacity needed for data storage. It is also because auto matic equipment is available to process the test data.

After the transistors are tested, the punched cards are run through automatic sorting equipment to determine the status of each transistor. This equipment punches an "accept" or "reject" digit on each test card and then separates the cards with respect to this information. The two groups of punched cards then contain the required information—which transistors are acceptable for ECO and which are rejects. The data on each punched card can then be automatically printed on large typed sheets to permit a study of the characteristics of each transistor. Other useful information can be automatically obtained from the punched cards, the most important being a "histogram." The information on the histogram may be used to check quality control on each lot of transistors through comparison with previous histograms.

The first 20 columns of the punched card identify the transistor, list the number of times it has been tested, and display its status. The information obtained from the automatic tester is located in columns 21 to 63. Columns 64 through 80 contain information on temperature, humidity, package type, and transistor location on a package. This indicates a great flexibility in the tester and the machine-card storage to allow such a great deal of data to be taken.

The automatic tester performs its tests on each transistor successively. In cases where only partial information is desired the tester can be made to skip specified individual tests. Also, each test circuit is arranged to lend itself easily to any changes in test parameters that might be required. The seven tests are:

(1) dc alpha

(2) Collector leakage current

(3) Emitter leakage current

(4) Collector junction breakdown

(5) Emitter junction breakdown

(6) Base resistance

(7) Electrical reach-through

Since its installation in 1956, the transistor tester has tested over 29,000 transistors, and completed over 114,000 test cycles. Many of these transistors have been tested several times. Besides providing a measuring stick to ensure that each transistor has met the initial test specifications, the tester has proved a useful and valuable tool for re-testing transistors in packages returned from the system. In this capacity, the tester plays an important part in collecting data on the performance of the Electronic Central Office of the future.

World's Largest Antenna For Space Communications

The world's largest horn antenna, protected by a radome about as high as a 13-story building, will be installed on a hilltop in western Maine as part of the Bell System's new experimental space communications ground station. The horn was designed by scientists and engineers at Bell Laboratories and will be ready for operation early next year.

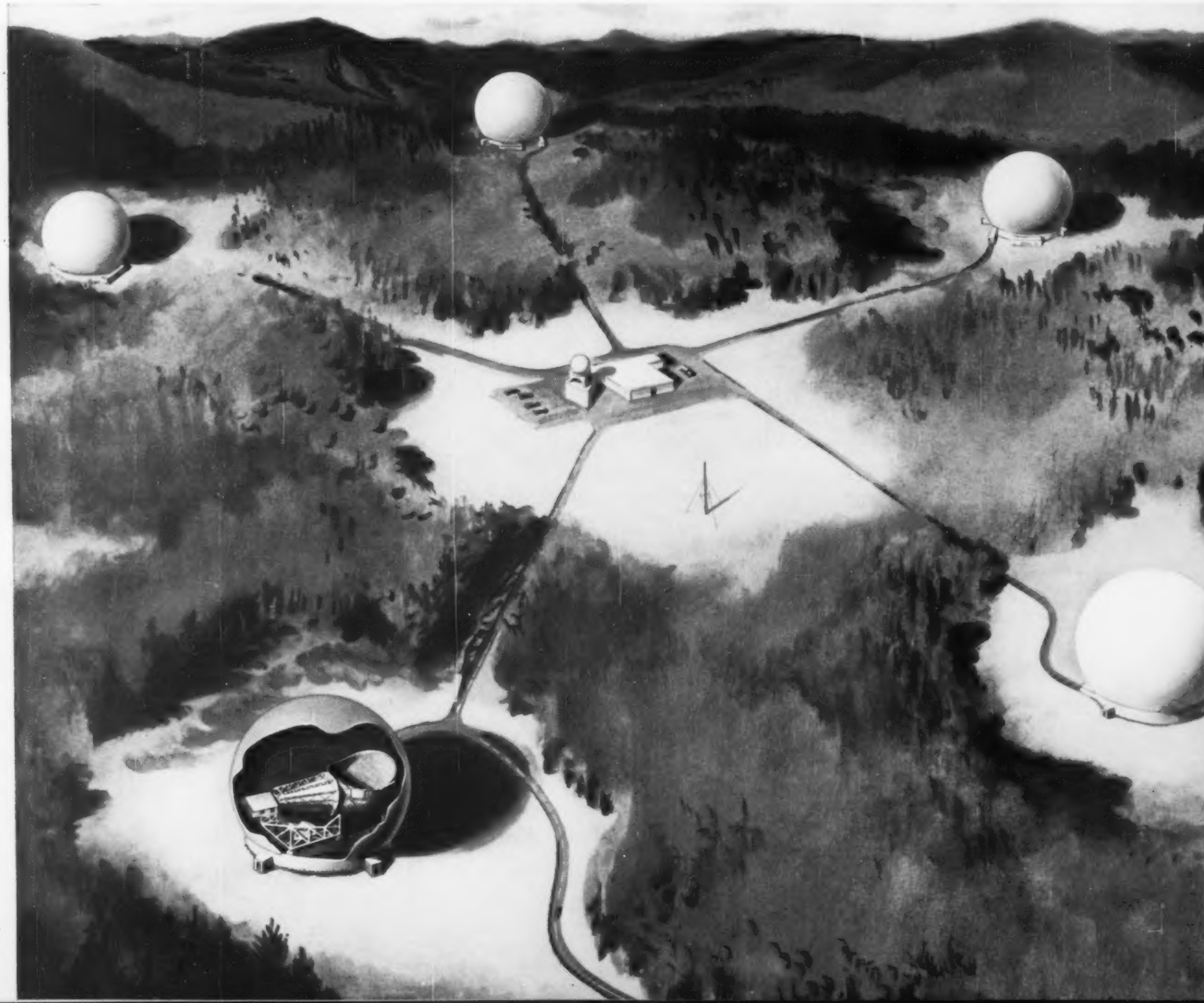
Site of the antenna will be a 1,000 acre tract in western Maine, about 75 miles from Portland, near the town of Rumford. Workmen already are clearing parts of the tract for Bell System space communications tests.

The new antenna will do two things: beam signals to a satellite, which will then relay them to Europe, and serve as a receiver for faint signals from Europe relayed to the station via the satellite.

The horn antenna will be a 250-ton steel and aluminum structure, 177 feet long and 94 feet high. It will be protected from wind and weather by a radome, supported by air pressure, 210 feet wide, 161 feet high. The radome will enclose about twice the space of the seating area in New York's Radio City Music Hall, and is designed to weather the strongest anticipated gales. Its skin will be made of three acres of synthetic rubber and fabric 1/16 inch thick, weighing 20 tons.

The horn will rotate on two concentric circular tracks, and will also "roll" about its horizontal axis so that it can follow a satellite at any elevation. Carried around on the structure with the

Experimental satellite-communications ground station. Antenna in cutaway radome will be built this year. A second antenna will be used to maintain communications as one satellite dips below the horizon and another rises. Third will take over during maintenance; fourth and fifth will communicate with overseas points not linked by the first pair. Antennas surround control building.



horn will be two "houses" about as large as moderate-sized dwellings. One house, about 40 feet square and located near the base of the antenna, will enclose machinery used to control the antenna position and other auxiliary equipment.

The other house, about 30 feet square and mounted at the "small" end of the horn, will contain radio apparatus. Included in this receiving equipment will be a traveling-wave maser amplifier invented at Bell Laboratories.

The radome will be supported by positive air pressure of 1/10 of a pound per square inch greater than the outside atmospheric pressure. It will be anchored to the top of a 14-foot wall encircling the antenna base. People with equipment, and even full-sized trailer trucks, will enter and leave the radome through attached buildings equipped with air locks.

This station, the most advanced complex of facilities in the space communications field will cost an estimated 7 million dollars. Construction of the complex is expected to begin this month.

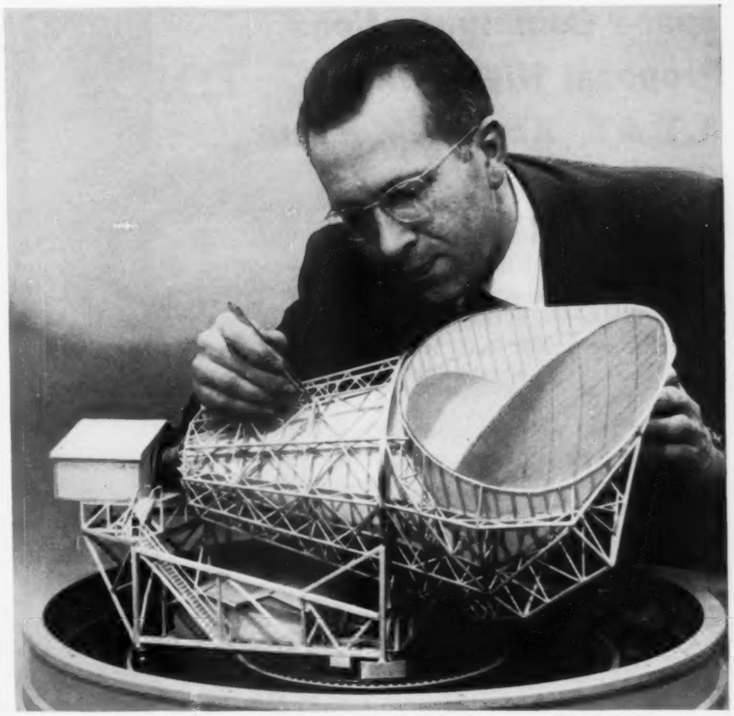
Rumford's antenna will be an enlarged version of the horn antenna at Bell Laboratories Holmdel, N. J., location, which was used successfully for Project Echo. However, the Rumford antenna will provide nine times as much antenna surface.

The Rumford area offered several advantages:

It is far from routes of microwave radio relay stations that operate on the same frequency bands to be used for the satellite experiments. Because signals from satellites are very weak, they are especially vulnerable to interference from signals in the same frequencies—even those considered weak by ordinary standards.

Topographically the site is well suited. It is a broad, saucer-shaped hill only 900 feet high and ringed by mountains up to 3800 feet high that help block off stray radio interference from other areas. The mountains are not so high that they will block communications with satellites.

Also, the site is near a highway.



A. O. Schwartz of the Military Reliability Engineering Department examines a model of the world's largest horn antenna. Note the small circular tracks used to rotate the antenna horizontally.

Workers are now building an access road from the highway to the site.

Bell Laboratories will continue to carry out basic radio research at its Holmdel ground station, for much remains to be done in the space-communications field.

From Rumford, the Bell System will conduct experimental transatlantic space communications, cooperating with telephone administrations abroad. These tie in with plans for a satellite-communications system.

Space communications systems are a natural supplement to, and extension of, existing common carrier networks. The Bell System handled four million overseas telephone calls in 1960, and the volume is growing at the rate of about 20 per cent each year. A satellite system would provide not only telephone, but also high-speed data and live television channels overseas.

The A. T. & T. Co. has announced that its proposed system would eventually use from 30 to 50 satellites to link countries all over the world. It has offered to repay the cost to the government of launching experimental satellites. Cost of operating the system would be paid by the Bell System and telephone organizations of other countries—just as costs of underseas cables are now shared.

After the Rumford station is used for experiments, the Bell System hopes to use it for commercial traffic.

Although specific sites for ground stations in other countries have not been announced, the British, French and West German communications administrations plan to take part.

The A. T. & T. Co. has indicated that the Rumford facilities will be made available to the National Aeronautics and Space Administration.

Space Communications Proposal Highlights A.T.&T. Annual Meeting

The Bell System is prepared to deliver the first of several experimental satellites by Christmas if permission is forthcoming promptly to launch a satellite under appropriate government supervision. Frederick R. Kappel, A.T.&T. president, made this statement April 19 to more than 18,000 share owners attending the company's annual meeting in Chicago.

Saying that we have made definite and sound proposals for a space-communications system, Mr. Kappel pointed out that we have the technical know-how to put these proposals into effect. "We can act promptly and there is a great need for prompt action." He said the demand for international communication services is growing very fast and both ocean cables and communication satellites will be needed.

Share owners who attended the first A.T.&T. meeting ever held outside New York applauded Mr. Kappel when he said he wanted to see this country the "unquestioned leader in space communications."

In describing the proposed satellite-communication system, Mr. Kappel made these major points:

▶ The system would be operated under Government regulation.

▶ It would be operated jointly with the communication agencies of foreign countries; they would own the terminals in their countries and we would work out equitable arrangements for sharing the cost of the satellites.

▶ It would be available to other common carrier companies engaged in international communications for any services the FCC authorized them to provide.

▶ Much equipment we would use in such a system would be obtained from other companies on a competitive basis. This includes much of the "hardware" as well as rockets and launching services.

Mr. Kappel noted several advantages of the Bell System's 2½ billion dollar construction program, which he said is planned carefully "not only to take care of growth but also to invest in improvements that stimulate new uses of our network and increase operating efficiency." It also "prepares us to do more for our customers in the months and years ahead, strengthens our long-run capacity to earn, keeps employment up within the business and also in the industries that provide us with goods and services. Furthermore, some of the work will further increase our ability to meet possible defense emergencies."

F. R. Kappel answers questions at annual meeting of A.T.&T. shareholders in Chicago, Ill.

Mr. Kappel also discussed the function of Western Electric in the Bell System, and said "with all possible emphasis . . . A.T.&T. has no intention of spinning off Western Electric either now, in the near future, in the distant future, or at any time whatsoever."

Western Electric is vital to the system and "to separate it would be the dismemberment of this business and a major misfortune to our share owners as well as to our customers."

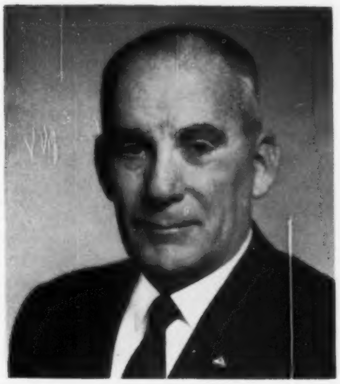
Mr. Kappel spoke of Bell Laboratories as "the greatest industrial research and development organization in the world, bar none." He said the Laboratories develops the finest communications equipment in the world and Western makes it—for the Bell Telephone Companies. "The telephone companies, the Laboratories and Western work together in intimate day-to-day cooperation, and they work toward the same service goals. This three-way teamwork is the main reason why this country has the best communication service in the world, and is the absolutely essential foundation for the Bell System's success as a business."

news in brief

M. H. Cook Takes New Assignment; M. B. McDavitt Elected Vice President

M. H. Cook, vice president of the Laboratories was recently assigned to long-range plans and operations for the Laboratories. In this post, Mr. Cook will report directly to President J. B. Fisk.

M. B. McDavitt, formerly director of Transmission Development, was elected a vice president by the board of directors of the Laboratories replacing Mr. Cook. In this capacity, Mr. McDavitt will be vice president in charge of apparatus development, design engineering, and quality assurance. In addition, he will be responsible for telegraphy, electromechanical PBX, and data systems development. A. C. Dickieson was named director of Transmission Development, succeeding Mr. McDavitt.



M. H. Cook

Mr. Cook began his telephone career with the Western Electric Company at its Hawthorne Works in Chicago, Ill. He was named superintendent of manufacturing engineering in 1940.

In 1944 he transferred to Bell Laboratories as director of specialty products development. Four years later he became director of apparatus and systems engineering, and in 1950 was named director of design engineering. He was elected a vice president of the Laboratories in 1954.

M. B. McDavitt

Mr. McDavitt began his Bell System career in 1925 in the Development and Research Department of the American Telephone and Telegraph Company and transferred with the department to Bell Laboratories in 1934. Since that time, he has been associated with the development of switching and transmission systems for the Bell System use. During World War II, he specialized in military communications systems planning and later served as director of the Bell Laboratories School for War Training. In 1952, he was named director of Transmission Development.

Bell Laboratories System Guides Satellite and Space Probe

Bell Laboratories Command Guidance System recently directed the booster stage of the Thor-Agena missile that sent the Air Force's Discoverer XXIII satellite into orbit and also guided the National Aeronautics and Space Administration's Explorer X space probe into its prescribed highly eccentric orbit.

Previous Discoverer first stages carried taped guidance instructions which were fed to automatic pilots. In this recent shot, however, the vital first stage was actually steered from the ground by corrective orders sent via a radar beam from a ground-based guidance computer to guidance equipment in the missile. This guidance system, originally developed for the Air Force's Titan missile, is manufactured by Western Electric and Remington Rand Univac.

New, miniaturized versions of the missile-borne guidance equipment, made of solid-state components, were used in Discoverer XXIII's first stage.

Discoverer XXIII is the latest in the Air Force's Discoverer series—a continuing program to develop a "space bus" test bed for putting payloads of various types into space and then retrieving the capsule in a designated recovery area. The discoverer capsules have brought back valuable engineering and research data on atmospheric phenomena and infrared radiation in the earth's atmosphere.

The guidance system for the Explorer X satellite was developed for the Air Force Ballistic Missile Division for use in the Titan I ICBM. This system is produced by the Western Electric Company.

This was the fourth successful use of the radio command guidance system for NASA's experimental satellites.

The Explorer X satellite, using the same combination of guidance and vehicle as in previous flights, carried a magnetometer probe on a course to the edge of interplanetary space (about 125,000 miles from earth) to measure magnetic fields and the flow of energy particles in space. The special magnetometers in this probe can detect weaker fields than could previous instruments, record the direction of the field, and measure the flux of low-energy particles in space.

Balloons To Carry ICBM Radar Test Targets

Bell Laboratories' engineers at the Whippany location have begun launching a series of 40-inch, helium-filled balloons, each carrying aloft a cantaloupe-sized metal sphere to serve as a test target for radar. The purpose is to obtain precise measurements on a radar designed to track intercontinental ballistic missiles.

The balloons, similar to those used in weather observation, will be visible to the naked eye up to several thousand feet. The test target—a small aluminum ball—offers a stable reflective surface for testing the long-range radars. A small spherical shape reflects a slight but constant amount of radar energy back to the radar antenna for precise evaluation of its performance.

A half dozen or more of the balloons will be released during May at the rate of about one or two a day when the weather is suitable. Winds may carry them out to sea or over the northeast coastal area.

After the balloons rise above 45,000 feet, they will burst. Small parachutes are attached to the four-ounce balls so that no one will be injured when they fall back to earth.

Western Electric Business Hits Peak

The demand for Western Electric's products and services was never higher than it was last year, according to the 1960 annual report released last month.

The production of telephones rose from 7,017,000 in 1959 to 7,640,000 in 1960. Western Electric produced more than 3.4 million lines of dial central-office switching equipment and 155 billion conductor feet of cable.

"To put it differently," the report continued, "enough telephones were produced in 1960 to provide a set for practically every man, woman and child in New York City; enough dial central office equipment to serve all Bell telephones now in service in the states of Pennsylvania, Massachusetts and Oregon and enough wire in cable to circle the earth at the equator more than a thousand times."

Military and space work accounted for about 27 per cent of the year's business measured in sales. This would be valued at more than $724,000,000, with more than half going to subcontractors and suppliers.

It also pointed out that about 90 per cent of the nearly 40,000 concerns from which Western Electric bought goods and services were companies with fewer than 500 employees. More than 6800 of these suppliers were found to be new sources for the company last year.

Net income increased to $124,490,000 from $102,188,000 a year ago. Retained earnings at year-end were $355,158,000, up from $298,605,000 at the end of 1959.

Transatlantic and Caribbean Cables Planned

The Federal Communication Commission recently authorized A.T.&T. to start laying the first transatlantic telephone cable to connect the U. S. and Great Britain directly. Both of the present two transatlantic cables, one to Britain and one to France, begin at Newfoundland and are connected to U. S. telephone circuits by Canadian land extensions.

The new cable will extend from the New Jersey coast between Atlantic City and Manahawkin to England near Widemouth Bay. It will be about 3500 nautical miles long and probably will be completed in 1963. It will be jointly owned by A.T.&T. and the British Post Office, which is responsible for telephone service in Great Britain. A.T.&T.'s share of the cost will be about $28 million.

The cable will provide 128 voice-grade circuits, meaning it can carry up to 128 telephone calls or other transmissions simultaneously.

U. S.-Jamaica Cable

A large-capacity undersea telephone cable between the United States and Jamaica in the British West Indies will use rigid-type repeaters developed by Bell Laboratories. This will be the first time these new repeaters have been used.

The cable, scheduled to be completed by late 1962, will serve as a major artery in an oceanic telephone network planned for Caribbean and South America points. It will be the first of a new type of telephone cable system designed to handle up to 128 voice circuits. This is more than three times the capacity of the first transoceanic telephone cable when it was first laid four years ago.

Initially, the system will provide high-quality circuits for U. S.-Jamaica communications. Ultimately, the cable also will be used for connections to other locations in the Caribbean and South America. The system will be owned jointly by A.T.&T. and Wireless West Indies, Ltd., a British company.

The proposed system, a single cable designed for two-way transmission, will extend some 850 miles between Florida City and Jamaica. Newly developed "armorless" cable will be used in the deep-sea section. This cable has a plastic outer coating instead of armor wires and a stranded steel core for tensile strength.

M. J. Kelly Appointed NASA Consultant

The National Aeronautics and Space Administration recently appointed Mervin J. Kelly as special consultant to the Administrator, James E. Webb. Dr. Kelly is a former President of Bell Laboratories and Chairman of the Laboratories Board of Directors.

Expand Laboratories At Laureldale And Allentown

Construction of additional facilities is underway at both the Laureldale and Allentown, Pa. branch locations of the Laboratories. At Laureldale, work is underway which will double the floor space. The new quarters will use the shell of a Western Electric Co. building.

The addition joins the present Laboratories facilities. Everything except the outer walls was ripped out of the Western Electric structure, paving the way for a completely new interior. When completed the Laboratories at Laureldale will have enough space to continue the present rate of expansion into 1962 without need for additional quarters.

The one-story addition will house individual laboratories stockrooms, a file area, and a conference room. All areas of the new building will be completely air-conditioned.

The 135 present employees at Laureldale plan to move into their new quarters in May.

At the Allentown branch laboratory, facilities are being expanded for development work in solid-state electronic devices. The construction work, which will make available additional office and manufacturing space for memory devices and other miniature items, is slated to begin this month.

The new addition will occupy two-thirds of the 140,000 square-foot, T-shaped extension of the present office building. Areas vacated by existing Laboratories facilities will be converted to enlarged manufacturing operations for Western Electric.

K. G. Compton Wins F. N. Speller Award

The National Association of Corrosion Engineers recently awarded K. G. Compton of the Chemical Research Department the Frank Newman Speller award.

Mr. Compton received the award for his many contributions to the techniques of studying underground and atmospheric corrosion. He designed and built the first vacuum tube voltmeter used in field corrosion tests and has several patents on electro-chemical processes and devices.

Mr. Compton has been chairman of many NACE committees and is the author of many papers on corrosion and protective coatings.

Testing Telephones For Tomorrow

Two hundred telephone customers in Richmond, Va., are product-testing two new telephones which represent a new concept of bringing the dial to the customer. This is done by incorporating the dial in the handset. These phones, the Trimline and the Contour, were designed at Bell Laboratories.

Both models feature dial night lights and are designed for both wall and desk-type installation. The trial in Richmond will determine whether or not one of these products may have a place in the Bell System.

Each model has a new space-saver dial. The finger wheel is smaller in diameter, but the finger holes are the same size as in the standard dial. To accomplish this, the space between the 1 and 0 on the dial is reduced. When a call is dialed, the finger stop moves clockwise to a position between the 8 and 9.

The Contour

The Trimline

TALKS

Following is a list of speakers, titles, and places of presentation for recent talks presented by members of Bell Laboratories.

AMERICAN PHYSICAL SOCIETY MEETING, Monterey, Calif.

Anderson, P. W., and Clogston, A. M., *An Antiferromagnetic Contribution to the Polarization of Free Electrons by Inner Shell Spins.*

Anderson, P. W., see Clogston, A. M.

Clogston, A. M., and Anderson, P. W., *Compensation of Ferromagnetic and Antiferromagnetic Contributions of Covalent Admixture in the Polarization of Free Electrons by Inner Shell Spins.*

Clogston, A. M., see Anderson, P. W.

Dillson, J. F., Jr., *Ferromagnetic Resonance in Silicon-Doped Yttrium Iron Garnet.*

Foredkin, D. R., and Wannier, G. H., *Existence of Transition-free Bands for a Crystal in a Homogeneous Electric Field.*

Galt, J. K., and Merritt, F. R., *Cyclotron Resonance Effects in Zinc.*

Geballe, T. H., and Matthias, B. T., *Superconducting Transition Temperature of Isotopes of Ruthenium.*

Geschwind, S., and Remeika, J. P., *Paramagnetic Resonance of Cu^{3+} in Al_2O_3.*

Gossard, A. C., *Correlations Between Superconductivity and NMR: Linewidths, Quadrupole Interactions and Impurity Effects.*

Hopfield, J. J., see Lax M.

Jaccarino, V., *NMR in the Intermetallic CaF_2 Structure: The Unusual Ga Knight Shift in $AuGa_2$.*

Jaccarino, V., see Walker, L. R.

Klauder, J. R., *Spin-echo Attenuation in Generalized Diffusion Models.*

Lax, M., *Time Reversal Selection Rules with Application to Intervalley Scattering.*

Lax, M., and Hopfield, J. J., *Selection Rules Connecting Different Points in the Brillorim Zone.*

Matthias, B. T., see Geballe, T. H.

Merritt, F. R., see Galt, J. K.

Remeika, J. P., see Geschwind, S.

Walker, L. R., Wertheim, G. K., and Jaccarino, V., *Interpretation of the Fe^{57} Isomer Shift.*

Walsh, W. M., Jr., *Paramagnetic Resonance of Trivalent Fe^{57} in Zinc Oxide.*

Wannier, G. H., see Foredkin, D. R.

Wertheim, G. K., see Walker, L. R.

Williams, G. A., *Double-Resonance Study of Relaxation in a Two-Spin System.*

QUANTUM ELECTRONICS CONFERENCE, Berkeley, Calif.

Bennett, W. R., Jr., *Radiative Lifetimes and Collision Transfer Cross Sections of Excited Atomic States.*

Geschwind, S., *Optical Detection of Paramagnetic Resonance in the Excited $\overline{E}(^2E)$ State of Cr^{3+} in Al_2O_3.*

Javan, A., *Optical Maser Oscillation in a Gaseous Discharge.*

Peter, M., *Paramagnetic Spectra of Fe^{+++} and Cr^{+++} in Moloclinic Tungstates.*

Schawlow, A. L., *Fine Structure and Properties of Chromium Fluorescence in Aluminum and Magnesium Oxide.*

OTHER TALKS

Ahearn, A. J., *Mass Spectrographic Studies of Impurities in Solids and Liquids,* Parma Research Center, Cleveland, Ohio; Bryn Mawr College, Physics Colloquium, Bryn Mawr, Pa.

Andrews, F. T., Jr., *A View of Systems Engineering at Bell Telephone Laboratories,* A.I.E.E. Winter General Meeting, N. Y. C.

Averill, R. M., see Newhall, E. E.

Baker, R. G., *The Use of Electroplated Metals in Static Contacts,* A.I.E.E Study Group on Electric Contacts, Public Service Bldg., Newark, N. J.

Black, H. S., *Global Communications via Artificial Earth Satellites,* Mich. Assoc. of Professions, Detroit, Mich.; A.I.E.E./I.R.E. Student Branch Polytechnic Institute of Brooklyn, N. Y.; Indianapolis Columbia Club, Indianapolis, Ind.

Chynoweth, A. G., *Field Ionization in Narrow p-n Junctions,* International Conf. on Semiconductors, Prague, Czechoslovakia.

Courtney-Pratt, J. S., and Fisher, M. G., *A Note on the Possibility of Photographing a Satellite Near the Moon,* Royal Photographic Soc. Conf. on Ultimate Sensitivity in Photography, London.

Cranna, N. G., see Leenov, D.

Dacey, G. C., *Optical Masers,* University of Pennsylvania, Philadelphia, Pa.; I.R.E. International Conv., Coliseum, Morse Hall, N. Y. C.

DeBenedictis, T., see Hansen, R. H.

Deutsch, M., *Experimental Studies of Cooperation and Bargaining,* Gard. Soc. Psychology Colloquium, Columbia University, N. Y. C.

Deutsch, M., *Studies of Conditions Affecting Cooperation,* Boston, University, Boston, Mass.

Dodson, G. A., and Howard, B. T., *High Stress Aging to Failure of Semiconductor Devices,* Seventh National Symposium on Reliability Quality Control, Wash., D. C.

Drew, G. G., and Yokelson, B. J., *Electronic Switching System,* Mid-Hudson Subsection I.R.E., Poughkeepsie, N. Y.

Fisher, M. G., see Courtney-Pratt, J. S.

Forster, J. H., see Leenov, D.

Galt, J. K., *Band Structure in Metals,* Reed College, Portland, Ore.

Galt, J. K., *Cyclotron Resonance in Metals*, University of Oregon, Eugene, Ore.

Galt, J. K., *Ferromagnetic Domains and Hysteresis*, I.R.E., Portland, Ore.

Garn, P. D., *Thermal Analysis—A Critique with Recommendations*, Analytical Chem. & Appl. Spectroscopy, Pittsburgh, Pa.

Garn, P. D., and Kessler, J. E., *Effluence Analysis as an Aid to Differential Thermal Analysis*, Analytical Chem. & Appl. Spectroscopy, Pittsburgh, Pa.

Garrett, C. G. B., *Solid-State Optical Masers*, University of Chicago, Chicago, Ill.

Gaunt, W. B., and Weller, D. C., *A 12-Kilobit, 5-Microsecond Twistor Variable Store*, 1961 Solid State Circuits Conf., Philadelphia, Pa.

Geballe, T. H., *Superconductivity Isotope Effect in Ruthenium*, University of Washington, Phys. Dept. Sem., Seattle, Wash.

Gershenzon, M., *Precipitation in Gallium Phosphide*, Electrochem. Soc. Meeting, Indianapolis, Ind.

Goldthwaite, Mrs. L. R., *Failure Rate Patterns*, Seminar on Reliability, Vanderbilt University, Nashville, Tenn.

Gyorgy, E. M., *Flux Reversal in Soft Ferromagnetics*, California Institute of Technology, Electrical Engineering Sem., Pasadena, Calif.

Hagstrum, H. D., *Auger Electron Ejection and Its Use in the Study of Solids*, University of Notre Dame, Phys. Colloquium, Notre Dame, Ind.; University of Illinois, Phys. Colloquium, Urbana, Ill.

Hamming, R. W., *Intellectual Implications of the Computer Revolution*, Stanford University, Stanford, Calif.

Hamming, R. W., *The Mechanization of Science*, IBM, San Jose, Calif.

Hansen, R. H., *Problems in the Preparation of Expanded Polypropylene Insulation*, Diamond Alkali Co., Painesville, Ohio.

Hansen, R. H., and DeBenedictis, T., *Studies of the Decomposition of Blowing Agents. I: A Method for Predicting Performance*, Am. Chem. Soc., Seton Hall University, South Orange, N. J.

Harris, G. G., *Basic Concepts of Stereo and Binaural Hearing*, A.I.E.E./I.R.E. Student Branch, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.

Harris, G. G., *What Is Psychoacoustics?*, Audio Engineering Soc. Conv., N. Y. C.

Hawkins, W. L., and Winslow, F. H., *Stabilization of Plastic Insulating Materials for Wire and Cable*, Conf. on Rubber & Plastics in Cables, London, England.

Healey, R. J., *A Control Circuit for p-n-p-n Regulated Rectifiers*, Solid State Circuits Conf., University of Pennsylvania, Philadelphia, Pa.

Herbst, R. T., *Machine Processing of Manufacturing Information for Digital Systems*, I.R.E., Charleston, S. C.

Hershey, J. H., *The Reliability Concept*, Seminar on Reliability, Vanderbilt University, Nashville, Tenn.

Hildebrandt, C. H., *The Nike-Hercules System*, Denville-Morris Hills Junior Chamber of Commerce, N. J.

Hornung, G. T., *Representation of Telephone Circuit Drawings in Data Processing Form for Expediting Development Programs*, National Machine Accountants Assoc., Columbus, Ohio.

Hostetler, W. E., *The 5-Type Artificial Larynx*, I.R.E., World War Memorial Bldg., Indianapolis, Ind.

Hostetler, W. E., *The 5-Type Artificial Larynx — An Electronic Voice*, Men's Organization of Broad Ripple Methodist Church, Indianapolis, Ind.

Howard, B. T., see Dodson, G. A.

Javan, A., *Optical Maser Oscillations in He-Ne Gas Discharge*, Columbia University, N. Y. C.

Kaenel, R. A., *Analog-to-Digital Converter Utilizes Tunnel Diodes*, 1961 International Solid-State Circuits Conf., Philadelphia, Pa.

Kennedy, R. A., *Mechanized Title Word Indexing of Internal Reports*, American University, Third Inst. on Information Storage & Retrieval, Wash., D. C.

Kessler, J. E., see Garn, P. D.

Ketchledge, R. W., *Engineering as a Career*, South Orange Junior High School, South Orange, N. J.

Kinariwala, B. K., *Analysis of Time-Varying Networks*, I.R.E. International Conv., N. Y. C.

King, B. G., see Sharpe, G. E.

Knox, K., *The Structures and Properties of Some Transition Metal Fluorides*, IBM Watson Lab., N. Y.

Kopel, P. S., see Newhall, E. E.

Kretsch, K. P., *Communications Research and the Engineer at Bell Telephone Laboratories*, Pennsylvania State University, Philadelphia, Pa.

Kuebler, N. A., see Nelson, L. S.

Kunzler, J. E., *Superconductivity in High Magnetic Fields at High Current Densities*, Princeton University, Princeton, N. J.; Brooklyn Polytechnic Institute, Brooklyn, N. Y.

Lee, C. Y., *Universal and Self-Reproducing Properties of Turing-Wang Machines*, Math. Colloquium, Ohio State University, Battelle Memorial Institute, Columbus, Ohio.

Leenov, D., Cranna, N. G., and Forster, J. H., *PIN Diodes for Protective Limiter Applications*, Solid State Circuits Conf., Philadelphia, Pa.

Levenbach, G. J., *Life-Testing of Electronic Components*, Binghamton, N. Y.

Liehr, A. D., *Colors of Ni(II) and V(III) Complexes*, Carnegie Inst. of Technology, Chem. Dept., Pittsburgh, Pa.

Liehr, A. D., *Conformational Stability of Inorganic Complexes in Degenerate Electronic States*, Catholic University of America, Wash., D. C.; National Res. Council, Ottawa, Canada.

TALKS (CONTINUED)

Loar, H. H., *Epitaxial Diffused Transistors,* I.R.E. PGED Meeting, N. Y. C.; PGED Meeting, Boston, Mass.

Loar, H. H., *The New Fast Transistors,* A.I.E.E./I.R.E. Student Chapter, Princeton University, Princeton, N. J.

Long, T. R., *Electrodeposited Memory Elements for a Nondestructive Memory,* Magnetism & Magnetic Materials Conf., Detroit, Mich.

Lovell, C. A., *Design of Digital Machines to Have No Down Time,* University of California Electrical Engineering School, Student-Faculty Colloquium, Berkeley, Calif.

Mardis, T. E., *Space Age Electronics,* I.R.E., New Orleans, La.

Meeker, T. R., *The Application of the Theory of Elastic Waves in Plates to the Design of Ultrasonic Disbursive Delay Lines,* I.R.E. International Conv., N. Y. C.

Meiboom, S., *Study of Chemical Kinetics by Nuclear Magnetic Resonance,* Stevens Inst. of Technology, Hoboken, N. J.

Meitzler, A. H., *Critical Frequencies Occurring in the Propagation of Elastic Pulses in Wires,* Fifty-Ninth Meeting of Acoustical Soc. of Am., Brown University, Providence, R. I.

Mendizza, A., *Problems and Preventive Measures of the Telephone Company,* Newark College of Engineering, Newark, N. J.

Miller, R. C., *Some Aspects of Ferroelectricity,* Caltech Sem., Pasadena, Calif.

Milner, P. C., *Oxide Electrodes in Battery Systems,* Electrochem., Soc., Cleveland, Ohio.

Morrison, J., *An Evaluation of Getter Flashing,* A.S.T.M., Wash., D. C.

Nelson, D. F., *Experiments on a Pulsed Ruby Optical Maser,* Polytechnic Institute of Brooklyn, N. Y. C.

Nelson, L. S., and Kuebler, N. A., *Degradation of Polymers by Heterogeneous Flash Heating,* Am. Chem. Soc., Seton Hall University, South Orange, N. J.

Newhall, E. E., *Magnetic Circuits for Logic and Storage,* Burroughs Auditorium, N. Y. C.

Newhall, E. E., Averill, R. M., and Kopel, P. S., *A Word Organized Memory Which Uses a Guided Flux for Reading and Writing,* International Solid-State Circuits Conf., Philadelphia, Pa.

Peter, M., *Magnetic Impurities in Metals,* Rensselaer Polytechnic Institute, Troy, N. Y.

Pierce, J. R., *Communication,* California Institute of Technology, Solid State Devices Colloquium, Pasadena, Calif.

Pollak, H. O., *Prolate Spheroidal Wave Functions, Fourier Transforms, and Uncertainty,* Philips Lab., Eindhoven, Holland; Aarhus University, Aarhus, Denmark.

Pollak, H. O., *The Work of the School Mathematics Study Group,* Sem. on Math. Knowledge Required by Physicist and Engineer, Brussels, Belgium; Aarhus University, Aarhus, Denmark; Scandinavian Committee for the Modernization of School Math., Oslo, Norway.

Rugnolo, D. S., *Information Theory and the Electromagnetic Field,* Cornell University Colloquium, Ithaca, N. Y.

Schawlow, A. L., *The Optical Maser,* Royal Canadian Institute, Toronto, Canada.

Sharpe, G. E., and King, B. G., *Low Gain, Wide Band Esaki Diode Amplifiers,* International Solid State Circuits Conf., Philadelphia, Pa.

Schwenker, J. E., *A Survey of Magnetic Memory Devices,* Oklahoma City Section A.I.E.E., Oklahoma City, Oklahoma.

Smith, G. E., *The Anomalous Skin Effect,* Cooperstown, N. Y.

Smolinsky, G., *Azene Chemistry: The Decomposition of Aryl Azides,* Fairleigh Dickinson University, Rutherford, N. J.

Sugano, S., *Spectroscopy for Solid-State Optical Masers,* Optical Soc. Am., Pittsburgh, Pa.

Sumner, E. E., *The 24-Channel PCM Exchange Carrier System,* A.I.E.E. Metropolitan Area Chapter, Western Union Bldg., N. Y. C.

Tebo, J. D., *Satellite Communications and Project Echo,* A.I.E.E./I.R.E. Meeting, Buffalo, N. Y.

Terry, M. E., *Computers in Processing Data,* Second Annual Clinic, A.S.Q.C., Univ. Student Center, Knoxville, Tenn.

Uenohara, M., and Wolfe, R., *Parametric Amplifier with Thermo-Electric Refrigeration,* Electron Devices Conf., Wash., D. C.

Wagner, R. S., *Relative Energy and Etching of Coherent Twin Boundaries in Germanium,* A.I.M.E. Meeting, St. Louis, Mo.

Wagner, R. S., *X-Ray Investigation of the Perfection of Silicon,* A.I.M.E. Semiconductor Conf., Boston, Mass.

Walsh, W. M., *Effects of Changes of Lattice Parameters on Iron Group Ions,* Varian Assoc., Palo Alto, Calif.

Weinreich, G., *Fine Structure of the Ground State of Donors in Germanium,* International Conf. on Semiconductors, Prague, Czechoslovakia.

Weller, D. C., see Gaunt, W. B.

Wernick, J. H., *Purification of Metals,* A.I.M.E. Phys. Metallurgy Gp., Mining Club, N. Y. C.

Wertheim, G. K., *Application of the Fe^{57} Mossbauer Effect in Magnetism,* Stevens Institute of Technology, Hoboken, N. J.

Winslow, F. H., see Hawkins, W. L.

Wolfe, R., see Uenohara, M.

Wood, E. A., *Symmetry and the Physical Properties of Crystals,* North Jersey Mineralogical Soc., Plainfield, N. J.; Newark Mineralogical Soc., Newark, N. J.

Yokelson, B. J., see Drew, G. G.

PATENTS

Following is a list of the inventors, titles and patent numbers of patents recently issued to members of the Laboratories.

Abbott, H. H.—*Telephone Conference Circuit*—2,975,237.

Andrews, E. G. and Vibbard, E. L.—*Automatic Calculator*—2,977,048.

Barrett, E. E., Kolensky, L. M. and Votaw, C. J.—*Selective Calling System*—2,974,187.

Bruce, E., Reenstra, W. A. and Ritchie, W. J.—*Two-Stage Line Concentrator System*—2,976,-367.

Cohen, E.—*Stabilized Timing Circuit*—2,976,487.

Cutler, C. C.—*Cosecant Squared Antenna-Reflector Systems*—2,976,535.

Dillon, J. F., Jr.—*Light Modulator*—2,974,568.

Egerton, L. and Flaschen, S. S.—*Method of Manufacture of Potassium-Sodium-Niobate Ceramics*—2,976,246.

Ellis, W. C. and Grenier, E. S.—*Low Temperature Drawing of Metal Wires*—2,974,778.

Feinstein, J.—*Magnetron*—2,976,-458.

Feldman, C. B. H.—*Selective Signal Recognition System*—2,974,281.

Flaschen, S. S. and Sauer, H. A.—*Ceramic Electromechanical Transducers*—2,974,203.

Flaschen, S. S. see Egerton, L.

Gent, E. W. and Werring, W. W.—*Machine for Embedding Beads in a Sheet*—2,975,822.

Goldrick, R. J., Kinsman, F. W. and Line, L.—*Apparatus for Stowing and Preparing for Overboarding a Submarine Cable Including Rigid Instrumentality Housings*—2,973,919.

Goodale, W. D., Jr. and Pferd, W.—*Telephone Pay Station*—2,977,419.

Gray, P. R.—*Incoming Trunk Circuit for In-Dialing Service*—2,976,368.

Grenier, E. S., see Ellis, W. C.

Hagelbarger, D. W. and Moore, E. F.—*Cryotron Circuits*—2,977,575.

Julesz, B.—*Economy in Television Transmission*—2,974,195.

Kinsman, F. W., see Goldrick, R. J.

Kolensky, L. M., see Barrett, E. E.

Line, L., see Goldrick, R. J.

Lowry, T. N.—*Telephone Subscriber's Supervisory Circuits*—2,977,420.

Mayo, J. S.—*Transistor Timing Circuit*—2,977,576.

McLeod, B. A.—*Random Signal Generator*—2,974,198.

Melhose, A. E.—*Hydrophone*—2,975,398.

Miller, L. E.—*Treatment of Semiconductive Devices*—2,974,075.

Moore, E. F., see Hagelbarger, D. W.

Mosing, L. W.—*Combined Telephone Handset and Stand*—D-189,877.

Mott, E. E.—*Pressure Compensated Underwater Transducer*—2,977,573.

Newhall, E. E. and Perucca, J. R.—*Magnetic Control Circuits*—2,976,472.

Perucca, J. R., see Newhall, E. E.

Pferd, W., see Goodale, W. D., Jr.

Pope, T. J.—*Hydrophone*—2,977,-572.

Quate, C. F.—*Low Noise Amplifier*—2,974,252.

Reenstra, W. A.—*Matrix Selecting Network*—2,976,520.

Reenstra, W. A., see Bruce, E.

Ritchie, W. J., see Bruce, E.

Robertson, G. I.—*Device for Instructing the Public in the Proper Use of Dial-Equipped Telephone Station Apparatus*—2,973,586.

Sauer, H. A., see Flaschen, S. S.

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Straube, H. M.—*Unidirectional Signal Translating Device*—2,975,301.

Terry, N. S.—*Telephone Station Identification System*—2,976,-366.

Vibbard, E. L., see Andrews, E. G.

Votaw, C. J., see Barrett, E. E.

Werring, W. W., see Gent, E. W.

Williams, G. H., Jr.—*Molding of Thermoplastic Materials*—2,975,487.

Young, W. R., Jr.—*Automatic Telephone Traffic Recorder Employing Magnetic Tapes*—2,976,365.

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Following is a list of the authors, titles, and places of publication of recent papers published by members of the Laboratories.

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Anderson, P. W., and Clogston, A. M., *An Antiferromagnetic Contribution to the Polarization of Free Electrons by Inner Shell Spins*, Bull. Am. Phys. Soc., 6, p. 124, Mar. 20, 1961.

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Baldwin, J. A., *A Magnetic Device for High-Speed Sensing of Small Currents*, Proc. Sp. Tech. Conf. on Nonlinear Magnetics & Magnetic Amplifiers, T121, pp. 134-140, Oct., 1960.

Ballman, A. A., see Laudise, R. A.

Bennett, W. R., *Amplification in Nonlinear Reactive Networks*, Trans. I.R.E., CT-7, pp. 440-446, Dec., 1960.

Benson, R. J., *Instrument-Gear Materials*, Prod. Engg., 32, pp. 37-41, Feb. 27, 1961.

Bogert, B. P., *An Observation of Free Oscillations of the Earth*, J. Geophys. Res., 66, pp. 643-646, Feb., 1961.

Bott, M. C., see Garn, P. D.

Brady, G. W., *Structure in Solutions*, Fast Fundamental Transfer Processes in Aqueous Biomolecular Systems, pp. 24-25, June, 1960.

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Clogston, A. M., and Jaccarino, V., *Susceptibilities and Negative Shifts of Intermetallic Compounds*, Phys. Rev., 121, pp. 1357-1362, Mar. 1, 1961.

Clogston, A. M., see Anderson, P. W.

Corenzwit, E., see Geballe, T. H.

Courtney-Pratt, J. S., *A Note on the Possibility of Photographying a Satellite Near the Moon*, J. Photo. Sci., 9, pp. 36-55, Jan.-Feb., 1961.

Crockett, J. H., see Laudise, R. A.

David, E. E., Jr., see Miller, J. E.

Dewald, J. F., *On the Transition to Metallic Behavior in Zinc Oxide*, The Phys. & Chem. of Solids, 17, pp. 334-335, Jan., 1961.

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Foredkin, D. R., and Wannier, G. H., *Existence of Transition-Free Bands for a Crystal in a Homogeneous Electric Field*, Bull. Am. Phys. Co., 6, p. 108, Mar. 20, 1961.

Garn, P. D., and Bott, M. C., *Determination of Anthraquinone in Capacitor Dielectrics*, Anal. Chem., 33, pp. 84-85, Jan., 1961.

Garn, P. D., and Kessler, J. E., *Thermogravimetry in Self-Generated Atmospheres*, Anal. Chem., 32, pp. 1563-1565, Nov., 1960.

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Geballe, T. H., and Matthias, B. T., *Superconducting Transition Temperature of Isotopes of Ruthenium*, Bull. Am. Phys Soc., 6, p. 122, Mar. 20, 1961.

Harmon, L. D., see Van Bergeijk, W. A.

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Haszko, S. E., *Rare Earth Gallium Compounds Having the Aluminum Boride Structure*, Trans. A.I.M.E. Metallurgical Soc., 221, p. 201, Feb., 1961.

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Kasuya, T., and LeCraw, R. C., *Relaxation Mechanism in Ferromagnetic Resonance*, Phys. Rev. Letters, 6, pp. 223-225, Mar. 1, 1961.

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King, B. G., and Sharpe, G. E., *Low Gain, Wide Band Esaki Diode Amplifiers*, Solid State Circuits Conf. Dig. Tech. Papers, pp. 98-99, Feb., 1961.

Klauder, J. R., *Spin-Echo Attenuation in Generalized Diffusion Models*, Bull. Am. Phys. Soc., 6, p. 103, Mar. 20, 1961.

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Mathews, M. V., see Miller, J. E.

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Meiboom, S., *Nuclear Magnetic Resonance Study of the Proton Transfer in Water*, J. Chem. Phys., 34, pp. 375-388, Feb., 1961.

Miller, J. E., Mathews, M. V., and David, E. E., Jr., *Pitch Synchronous Spectral Analysis of Voiced Sounds*, J. Acous. Soc. Am., 33, pp. 179-186, Feb. 1961.

Sharpe, G. E., see King, B. G.

Soden, R. R., see Van Uitert, L. G.

Spitzer, W. G., and Kleinman, D. A., *The Infrared Lattice Bands of Quartz*, Phys. Rev., 121, pp. 1324-1335, Mar. 1, 1961.

Van Bergeijk, W. A., and Harmon, L. D., *What Good Are Artificial Neurons?*, WADD Tech. Rep. No. 60-600 (Bionics), pp. 395-406, Mar., 1961.

Van Uitert, L. G., and Soden, R. R., *The Emission Spectra of Trivalent Thullium*, J. Chem. Phys., 34, pp. 276-279, Jan., 1961.

Von Aulock, W. H., *Properties of Phased Arrays* Proc. I.R.E., 48, pp. 1715-1727, Oct., 1960.

Wannier, G. H., see Foredkin, D. R.

THE AUTHORS

M. E. Ozenberger

M. E. Ozenberger was born near Wathena, Kansas and attended Baker University, Baldwin, Kansas. He started his Bell System career in 1928 with Southwestern Bell Telephone Company at St. Joseph, Missouri as a central-office craftsman. He spent three years as Wire Chief at Manhattan, Kansas after which he returned to St. Joseph where he served ten years as Chief Switchman. Mr. Ozenberger came to the Laboratories in 1954, on temporary assignment, where, as a member of the station systems group, he has been engaged in the design of No. 300 Switching System. On his 30th anniversary with the Bell System in 1958 he formally transferred to the Laboratories. Mr. Ozenberger is the author of "Voice Communication for Air Traffic Control" in this issue.

O. C. Olsen

O. C. Olsen, a native of Wellington, Ohio, received the B.E.E. degree in 1940 from Ohio State University and did graduate work in physics and mathematics at New York University. He joined Bell Laboratories in 1940 and was assigned to work on the trial installation of a UHF radiotelephone system. He also worked on the design of military communications equipment. After a four-year leave for service as a Major with the Air Corps., Mr. Olsen returned to the Laboratories in 1946. Since then he has been concerned with the development of manual and dial PBX switching equipment such as the 608A PBX, and 555 manual switchboard and the 756A Crossbar PBX. He has also done exploratory development work on the Electronic PBX. At present he is concerned with design of the 757A Crossbar PBX. Mr. Olsen is a member of Eta Kappa Nu. He is the co-author of "A Pushbutton PBX Switchboard" in this issue.

J. G. Walsh, the co-author of "A Pushbutton PBX Switchboard," was born in New York City. After attending the U.S. Army Signal Corps School in Fort Monmouth, New Jersey, he was an instructor in telephony there for one year. He joined the Engineering Department of Western Electric in 1923 and was later transferred to Bell Laboratories with that group. At the Laboratories, he was assigned to circuit development work on manual, step-by-step, No. 1 Crossbar, and PBX systems. Later he was a project engineer on the development of acoustic torpedoes. After the war he did circuit development work on No. 5 Crossbar. Since 1958 Mr. Walsh has supervised a group concerned with the development of the 608A PBX and the 757A PBX.

J. G. Walsh

T. E. Mardis, a native of Fayetteville, Arkansas, was educated abroad, receiving the B.S. in E.E. degree from the University of Leeds, in England. After a year with a British electronics firm he joined the United States Signal Corps and, during World War II, served as radar officer at Antiaircraft Batteries. In 1947 he joined the Western Electric Company North Carolina Plant as a test planning engineer. For eight years he was concerned with airborne communications and waveguide equipment. After a year of research and development on microwave components, with another company, he joined the Laboratories in 1956. He is presently at the North Carolina Laboratories where he is continuing his work in the microwave field. Tom Mardis is the author of "Techniques for Microwave Breakdown Measurements" in this issue.

T. E. Mardis

AUTHORS (CONTINUED)

Smith Harris was born in Vancouver, Wash. He received his B.A. degree from Emory University, Atlanta, Ga., in 1938, after which he taught language there until inducted into the Army in 1941. During the last 2½ years of service, he was military intelligence officer in the European

S. Harris

theater. Following his release, he worked for the Veterans Administration, Sears, Roebuck & Co., and Goodyear Service, which he left to attend Capitol Radio Institute in Washington, D. C. Upon graduation in 1952, he joined Bell Laboratories. Mr. Harris' entire service with the Laboratories has been in Outside Plant in the test set, armored cable, and armorless cable ocean groups. He is an associate member of the I.R.E. He is the author of "A Concentricity and Diameter Gage for Ocean Cable," appearing in this issue.

J. J. Mosko, a resident of Middletown, New Jersey, joined the Laboratories in 1937 and later became a member of the drafting group of the Apparatus Development Department. During World War II, he worked on components of the M-9 Gun Director. Later he was concerned with the development of the AMA Reader and the wire-spring multi-contact relay. In 1956, he transferred to the Common Systems equipment group of the Switching Systems Development Department. In this group he is engaged in the development of operator-training, service observing and test board equipment. Mr. Mosko attended Cooper Union School of Engineering and is the author of "Operator-Training Equipment" in this issue.

G. M. Lowry, a resident of Wayne, N. J. graduated from the Radio & Television Institute and joined the Western Electric Company in 1941. As assistant supervisor in the Special Products Division he was concerned with the

J. J. Mosko

G. M. Lowry

manufacture and testing of Signal Corp radio equipment, and modulation transformers for radar systems. After serving as an electronic technician in the navy, from 1944 to 1946, he returned to Western's engineering department to test-set equipment and mobile-radio plant protection work. In 1950 he transferred to the New York Telephone Company, in the Repair Department, maintaining switchboards and special purpose lines, and where his brother, J. P. Lowry, is a supervisor.

Mr. Lowry attended Stevens Institute of Technology and graduated from their Industries Training school in 1955. At that time he transferred to Bell Laboratories and has since been engaged in switching development and transistor testing for the Morris Electronic central office. He is an associate member of the I.R.E., and the author of the article "Testing Transistors for the Electronic Central Office" in this issue.


WATCH THIS SPACE
In a moment a new satellite will streak into view. Bell Laboratories may help guide it into orbit, for few are so eminently qualified in the science of missile guidance. Bell Laboratories' Command Guidance System has guided such trailblazers as Tiros and Echo into precise orbits. The same system will guide more new satellites into predetermined orbits as Bell Laboratories continues pioneering in outer space to improve communications on earth.
BELL TELEPHONE LABORATORIES
World center of communications research and development